Ethernet Fundamentals Overview: Part 1 (Mod 6)

CIS 81 and CST 311

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Cabrillo College

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Note to instructors

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- If you have downloaded this presentation from the Cisco Networking Academy Community FTP Center, this may not be my latest version of this PowerPoint.
- For the latest PowerPoints for all my CCNA, CCNP, and Wireless classes, please go to my web site:

  http://www.cabrillo.edu/~rgraziani/

  - The username is *cisco* and the password is *perlman* for all of my materials.
- If you have any questions on any of my materials or the curriculum, please feel free to email me at graziani@cabrillo.edu (I really don't mind helping.) Also, if you run across any typos or errors in my presentations, please let me know.
- I will add "(Updated – *date*)" next to each presentation on my web site that has been updated since these have been uploaded to the FTP center.

Thanks! Rick

Note to Students and Instructors

- Some of the information found in the Cisco online curriculum will <u>not</u> be taught in this course.
- Some of the information in this module or chapter will be discussed in much more detail in later modules or chapters.
- Some of the information contained at this point in the online curriculum has <u>not</u> been completely explained.
- So if you are feeling confused by many of the terms and information in the Cisco online curriculum, it is okay, we will learn what all this means LATER.
- Much of this information will become much clearer as we learn more and more about networking.
- Additional information will be added to this chapter and this course, which is more relevant to the goals of the Computer Networking and System Administration program.

Ethernet Fundamentals

Part 1

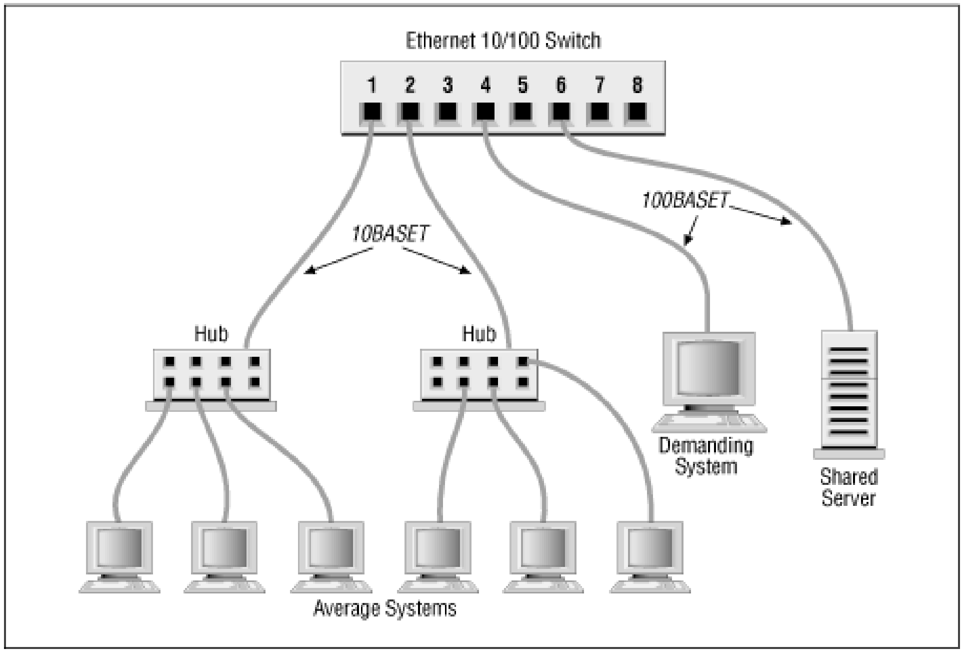
- Introduction to Ethernet

Part 2

- Layer 2 and Ethernet Switches
- Cables, Duplex, and Troubleshooting
- Ethernet and the OSI Model – more detail
- Ethernet frames – more detail

Introduction to Ethernet

Ethernet Local Area Networks (LANs)



- **LAN (Local Area Network)** - A group of computers and associated devices (printers, etc.) connected through a wired or wireless medium by networking devices (hubs, switches, routers) and administered by a single organization.
- **Ethernet** – The protocol used to communicate by the computers, associated devices, and networking devices.

Network Interface Card (NIC)

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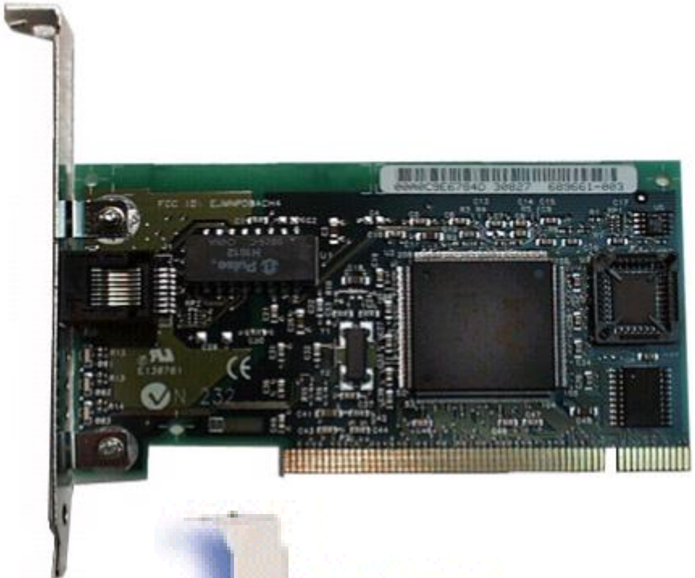
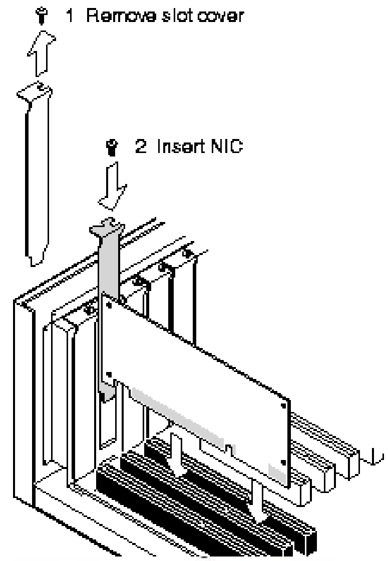
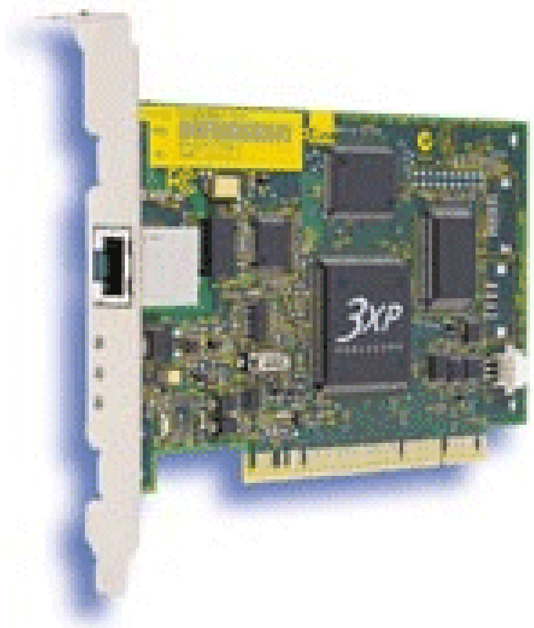




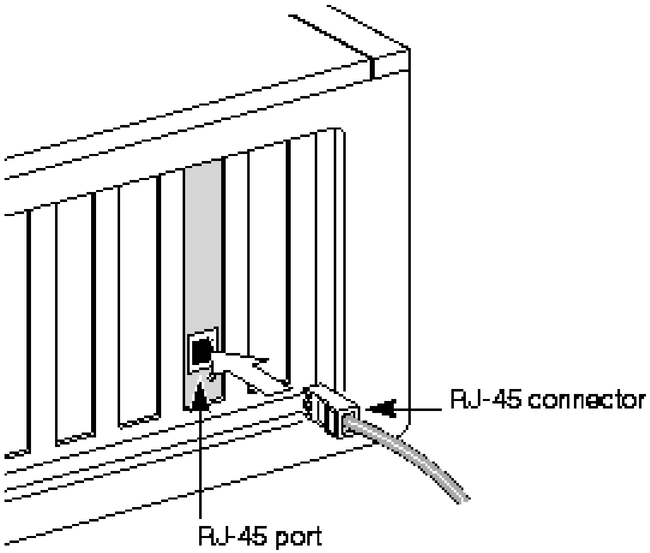


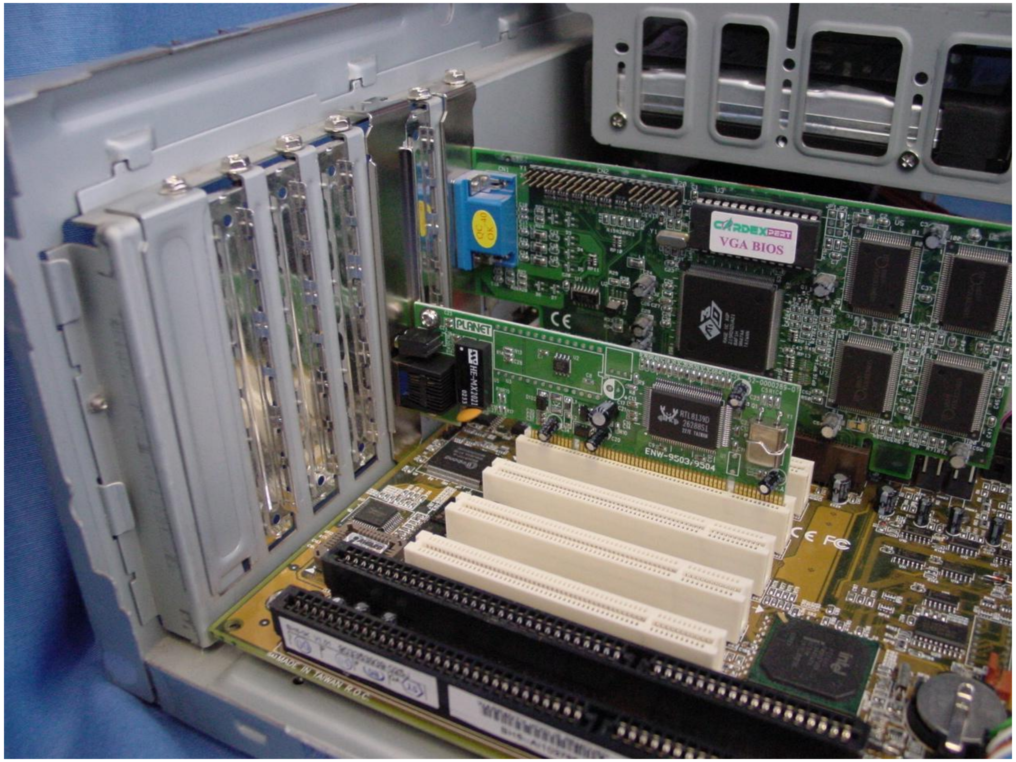
Network Interface Card (NIC)

Network Interface Card (NIC)

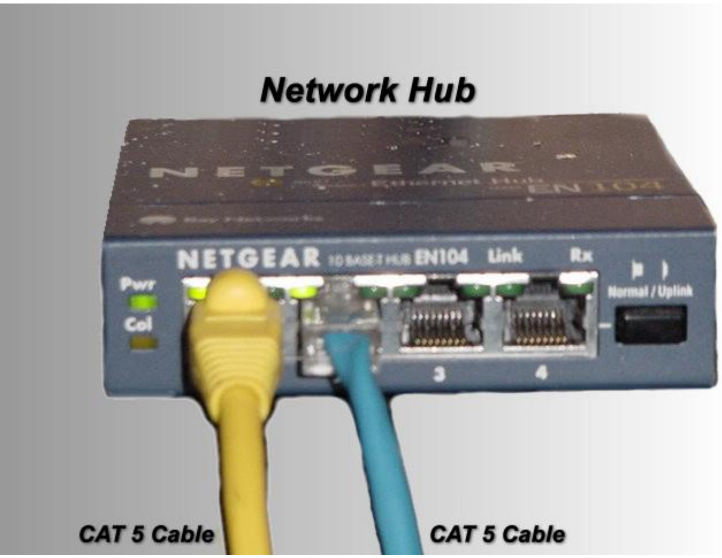
- Layer 2, Data Link Layer, device
- Connects the device (computer) to the LAN
- Responsible for the local Layer 2 address (later)
- Common Layer 2 NICs:
  - Ethernet
  - Token Ring
- Common Bandwidth
  - 10 Mbps, 10/100 Mbps, 10/100/1000 Mbps

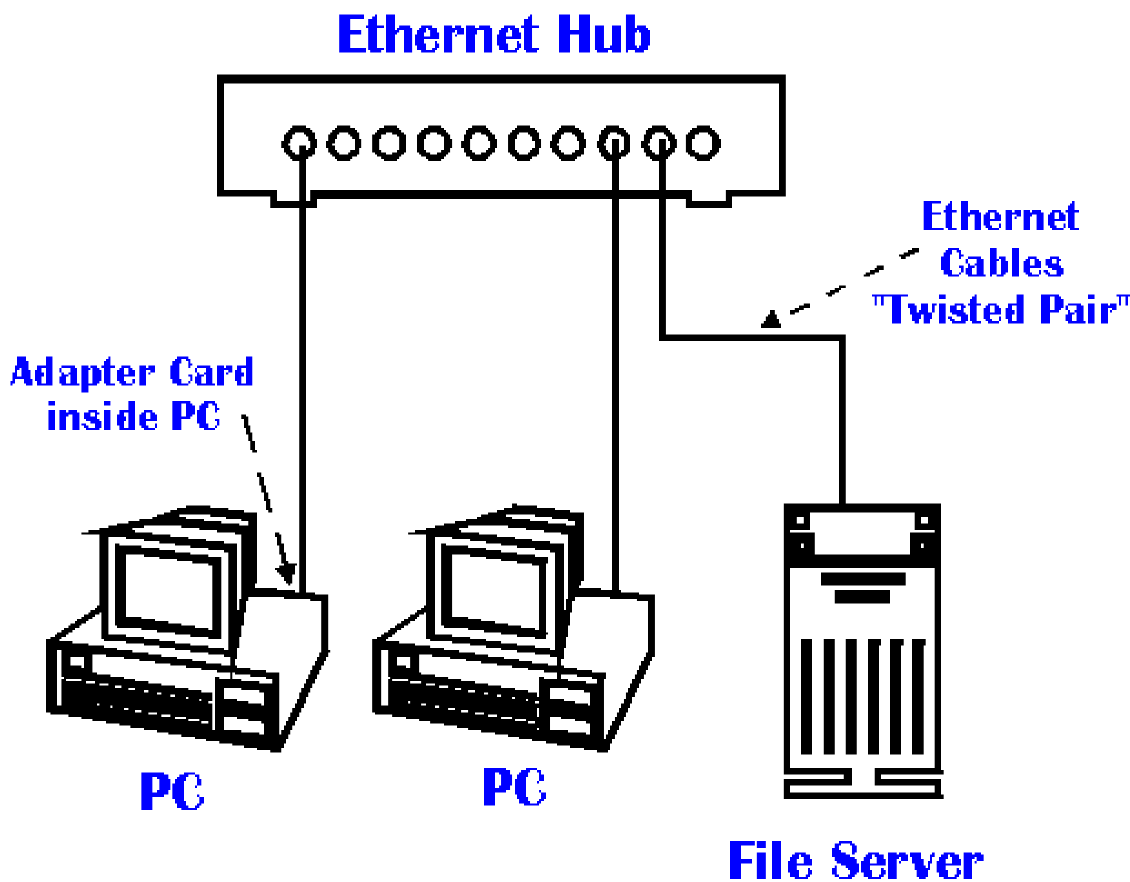
Tracing the Physical Connection
NIC (Network Interface Card)





Connecting the NIC to a Hub or Switch…





From PC to Ethernet Port…

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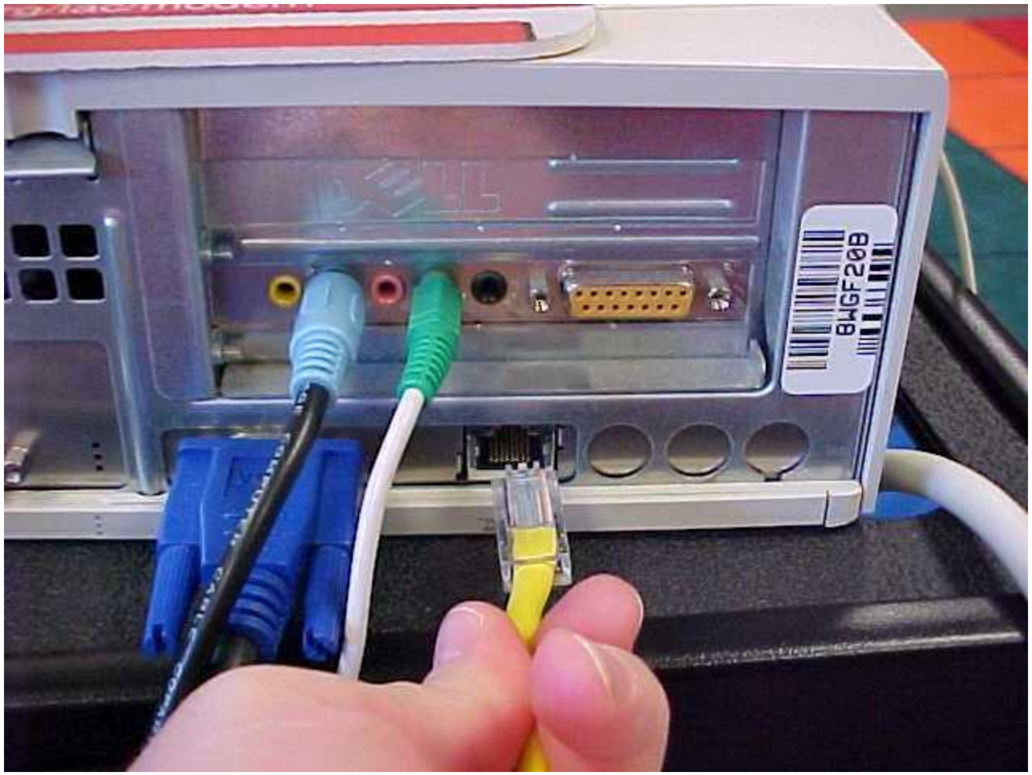
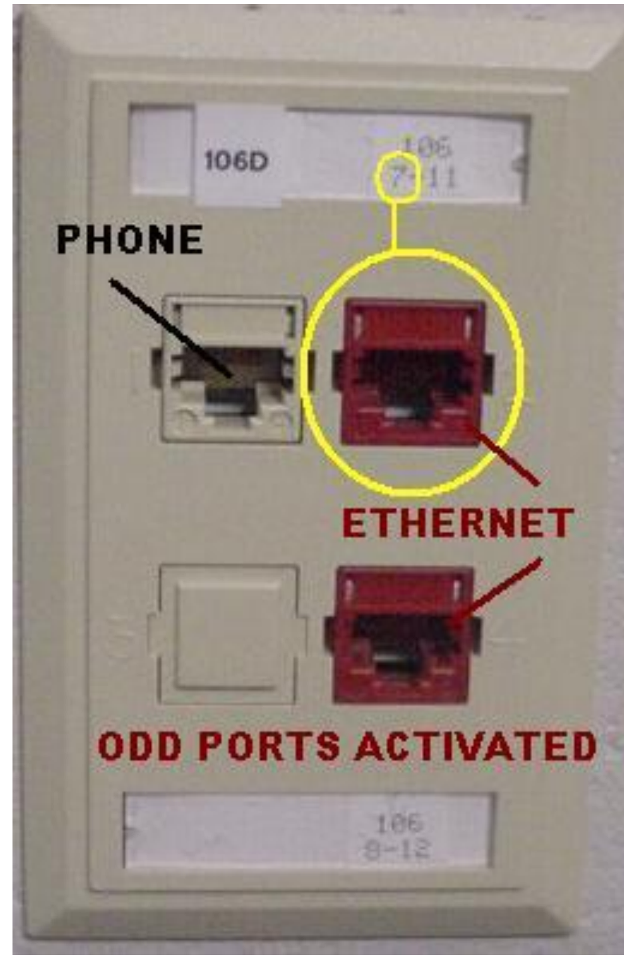
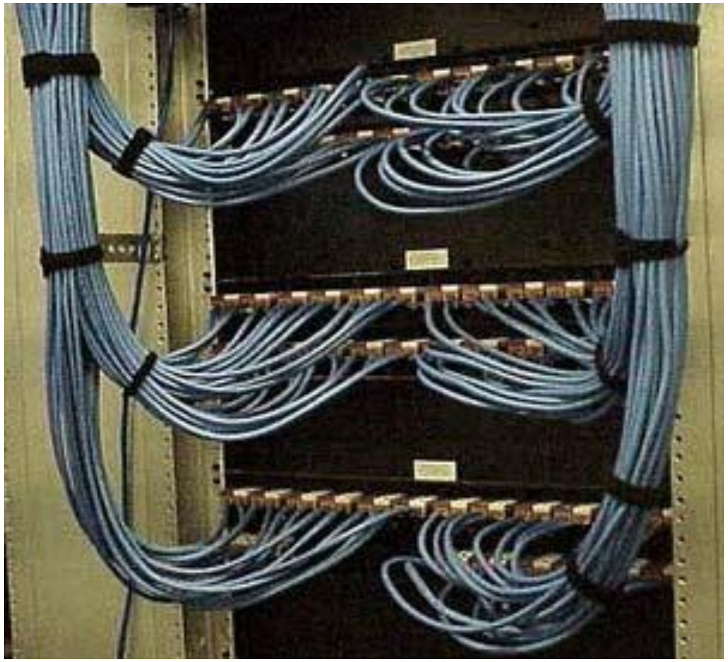


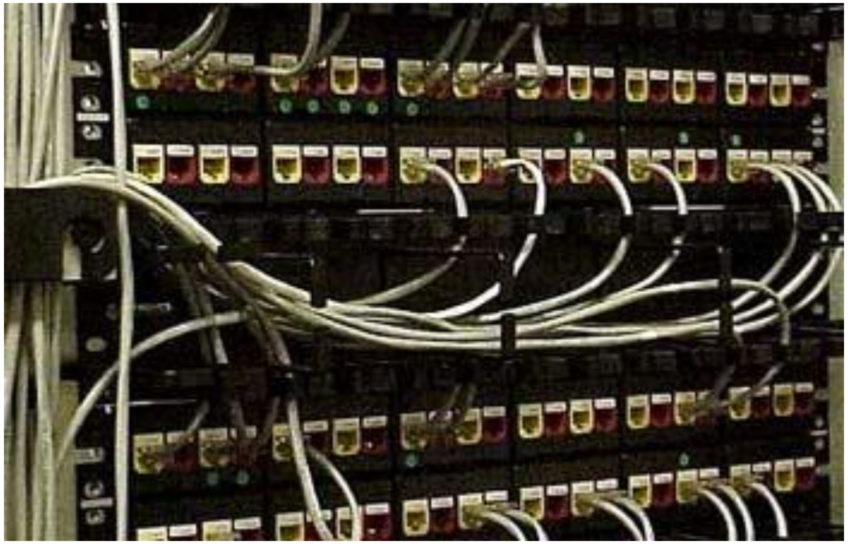


From Ethernet Port to Patch Panel…

Back View



Front View



From Patch Panel to Switch (or hub)

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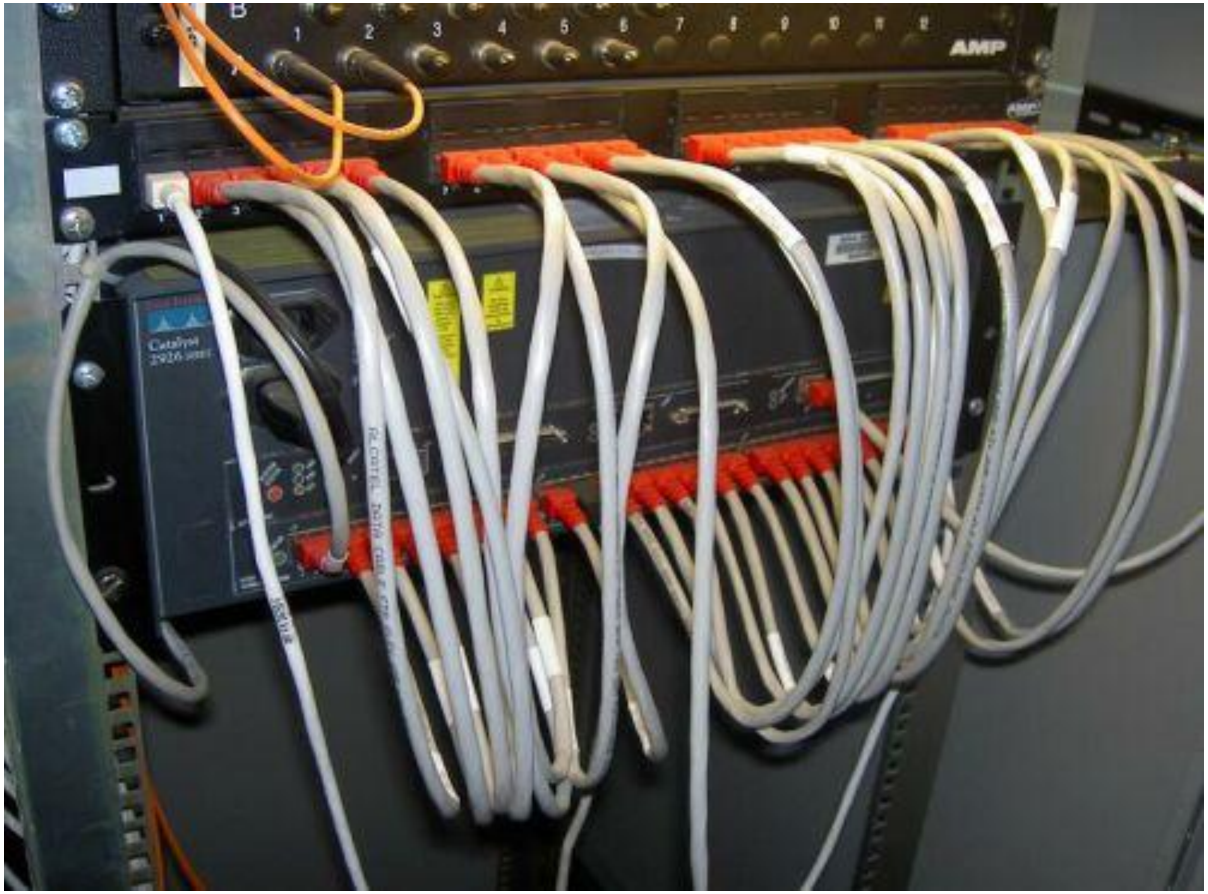
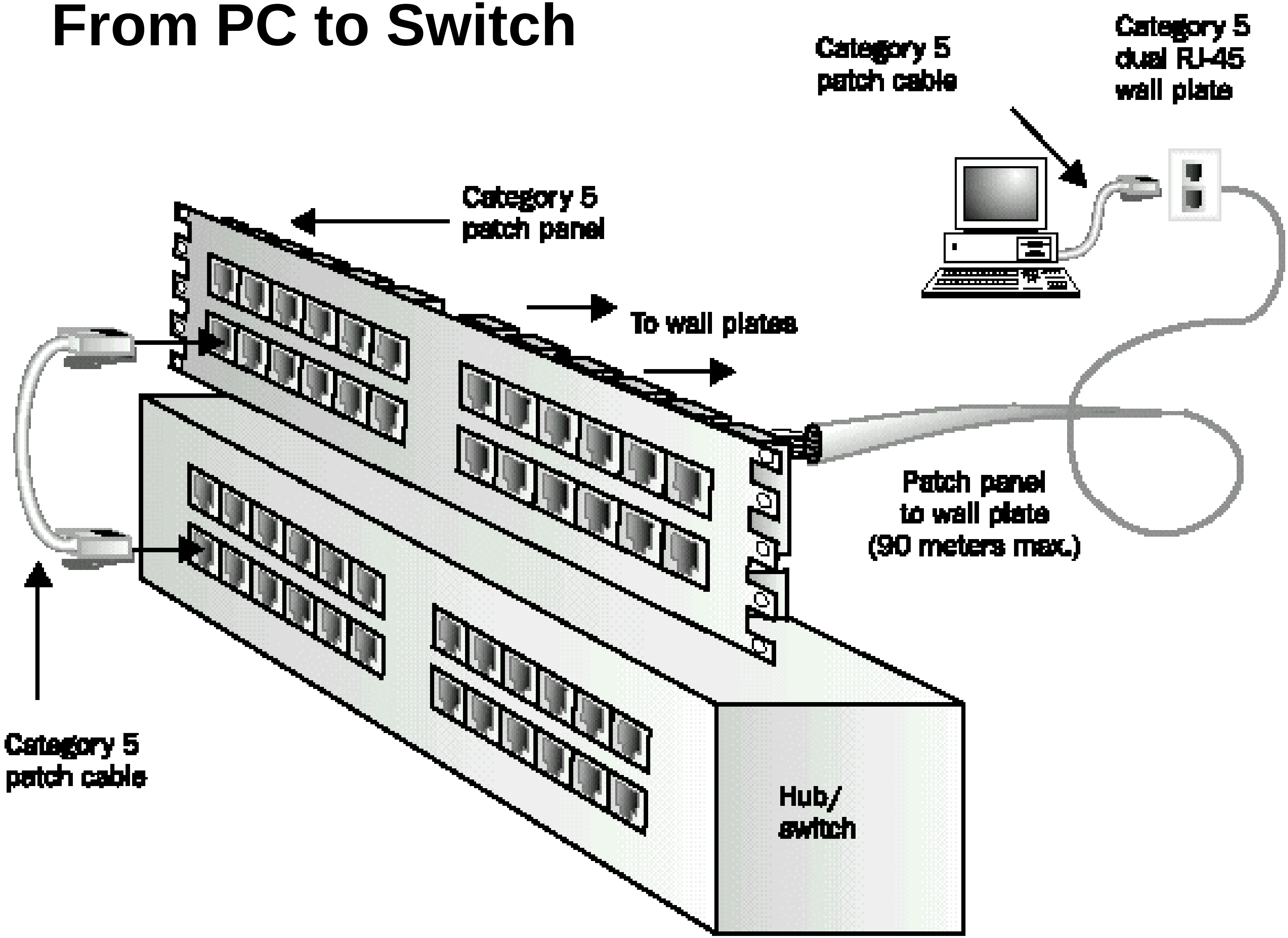
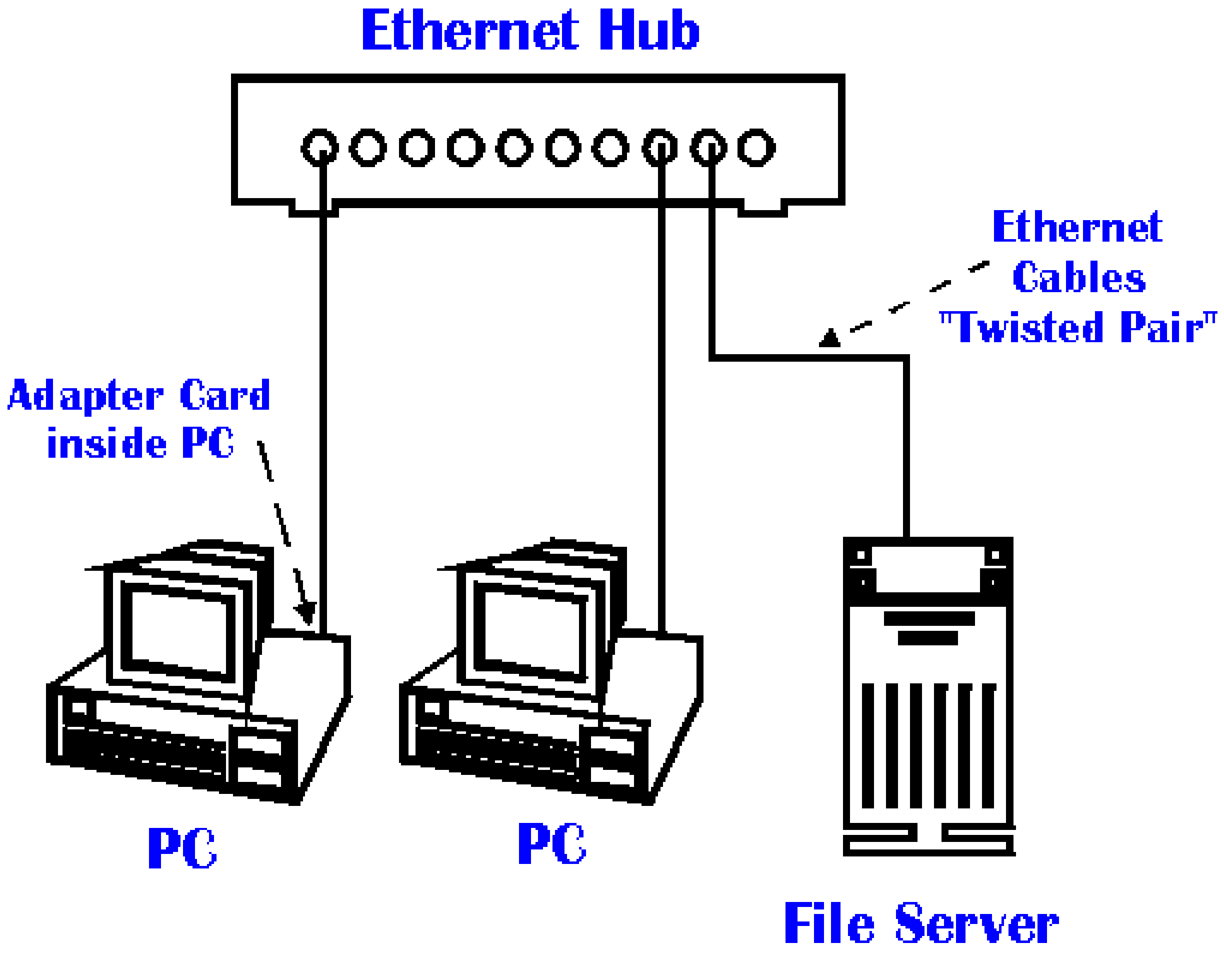


From PC to Switch



All of that is the same as this!



Trace your connection!

- Get a partner.
- On a piece of paper trace, draw, the connection from your computer to the hub or switch.
  - Is your computer connected to a wall plate data port?
  - Does your computer connection connect to a patch panel? If so, what is the patch panel number?
  - You computer connection will connect to a hub/switch. What is the port number?
- Label each item.

Our focus!

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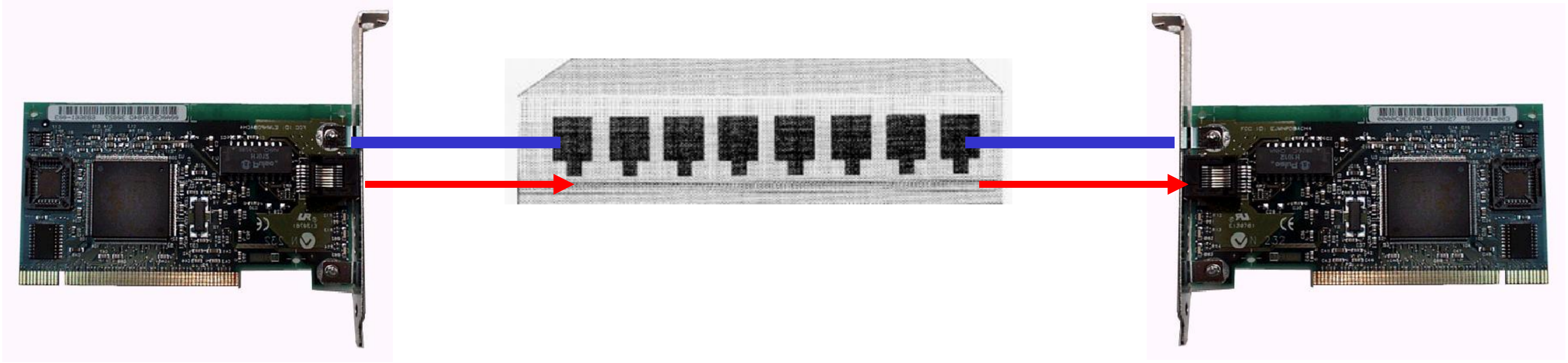
- Don't worry about what the information looks like.
- We are going to look at a Layer 2 Local Area Network protocol called Ethernet.
- This protocol is only concerned with how the information gets from one Ethernet host or device to another.
- In our examples, we will look at how Ethernet is used to transmit information from one computer to another computer, via one or more Ethernet network devices such as hubs (repeaters) and switches (bridges).



Ethernet and IEEE 802.3

Field Length, in Bytes

Ethernet

8	6	6	2	46-1500	4
Preamble	Destination Address	Source Address	Type	Data	FCS

- The Institute of Electrical and Electronic Engineers (IEEE) is one of several professional organizations that defines network standards.
- **IEEE 802.3** "Ethernet" is the predominant and best known LAN standards, along with 802.11 (WLAN).
- This standard includes the protocol used to "**frame**" the data by the sending Ethernet host computer.
- Most of the time, the term "Ethernet" is used to mean IEEE 802.3
- For the most part, Ethernet and IEEE 802.3 are used interchangeably, even though they are not really the same thing. (more later)

Ethernet "Data"

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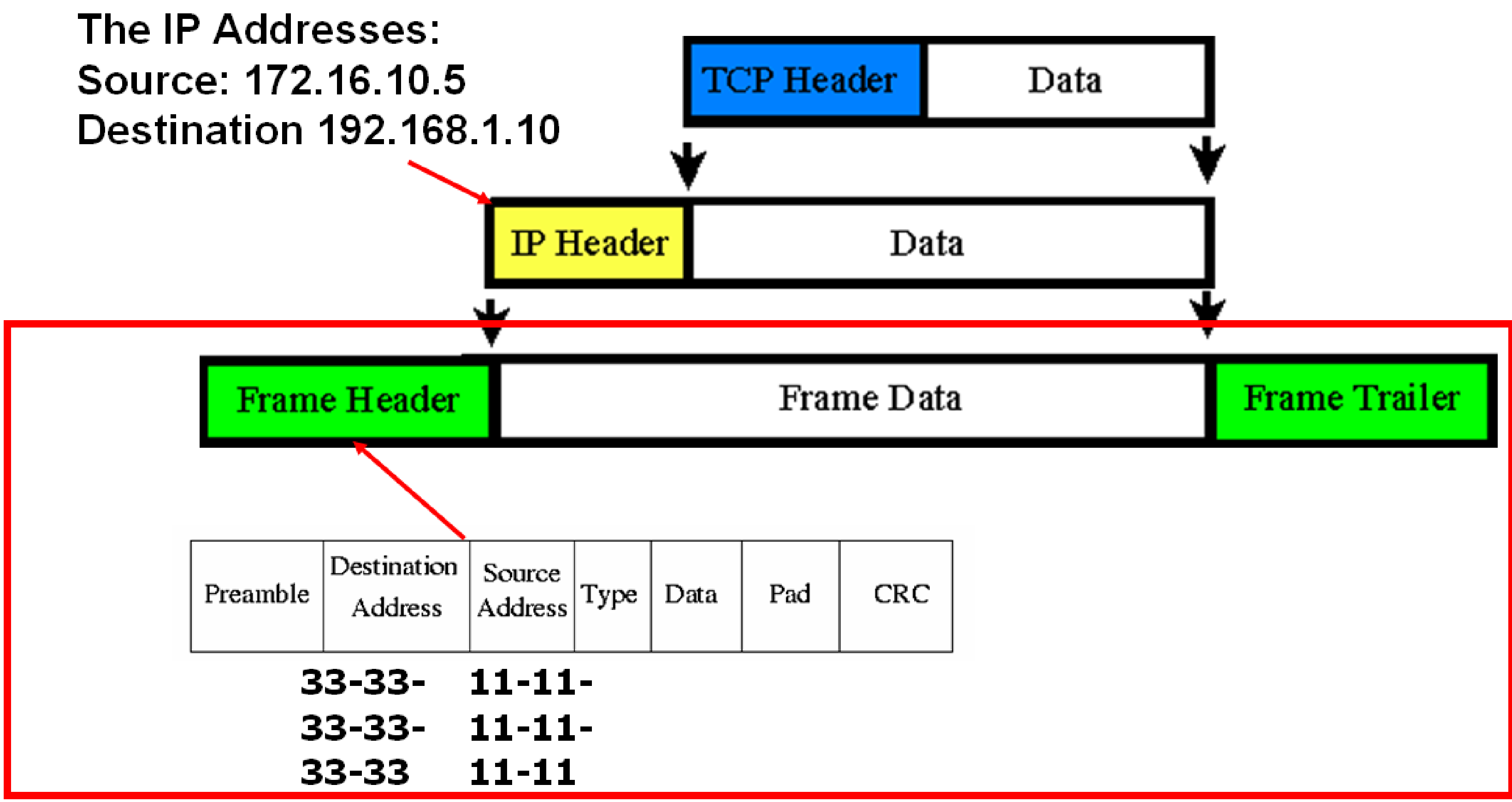
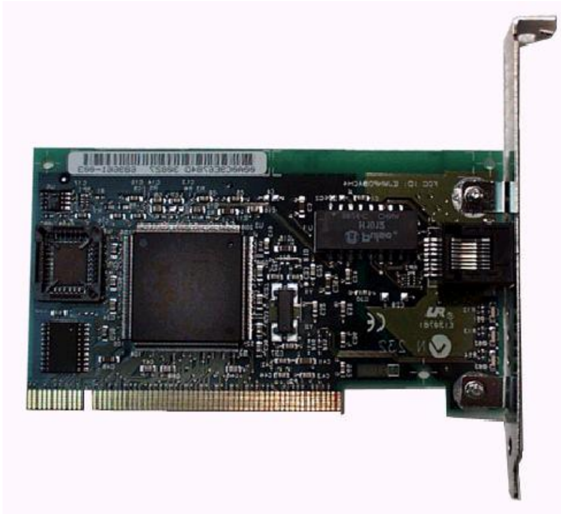
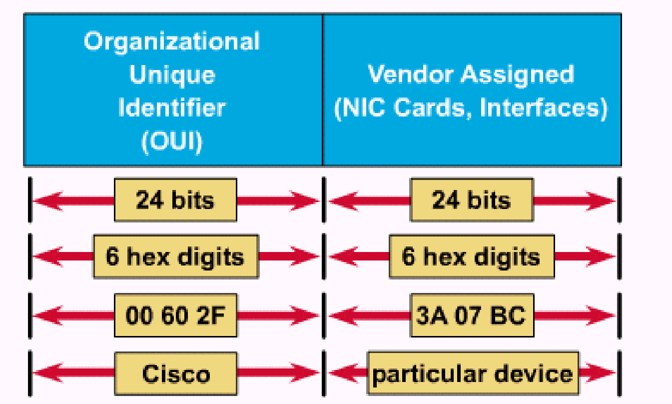
- Let's not worry right now about what the "data" is.
- We will discuss this later!



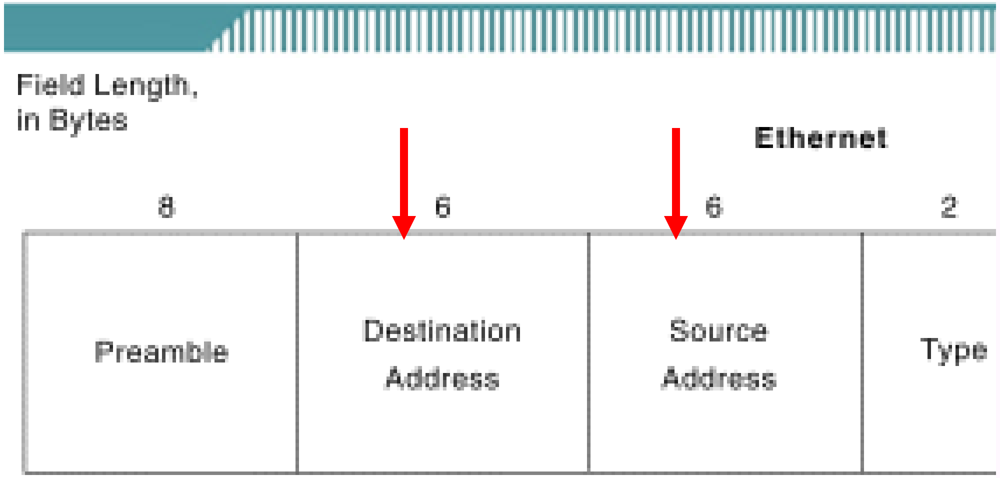
The MAC Address

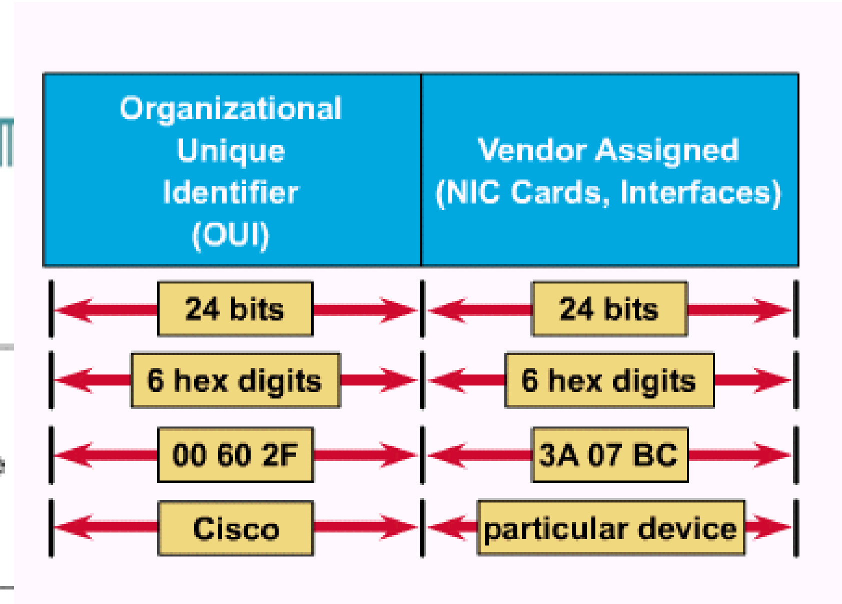




- Part of the Ethernet protocol includes the MAC (Media Access Control) - coming
- Every Ethernet NIC card has a unique MAC address.
- MAC addresses provide a way for computers to identify themselves.
- They give hosts a <u>permanent, unique name</u>.

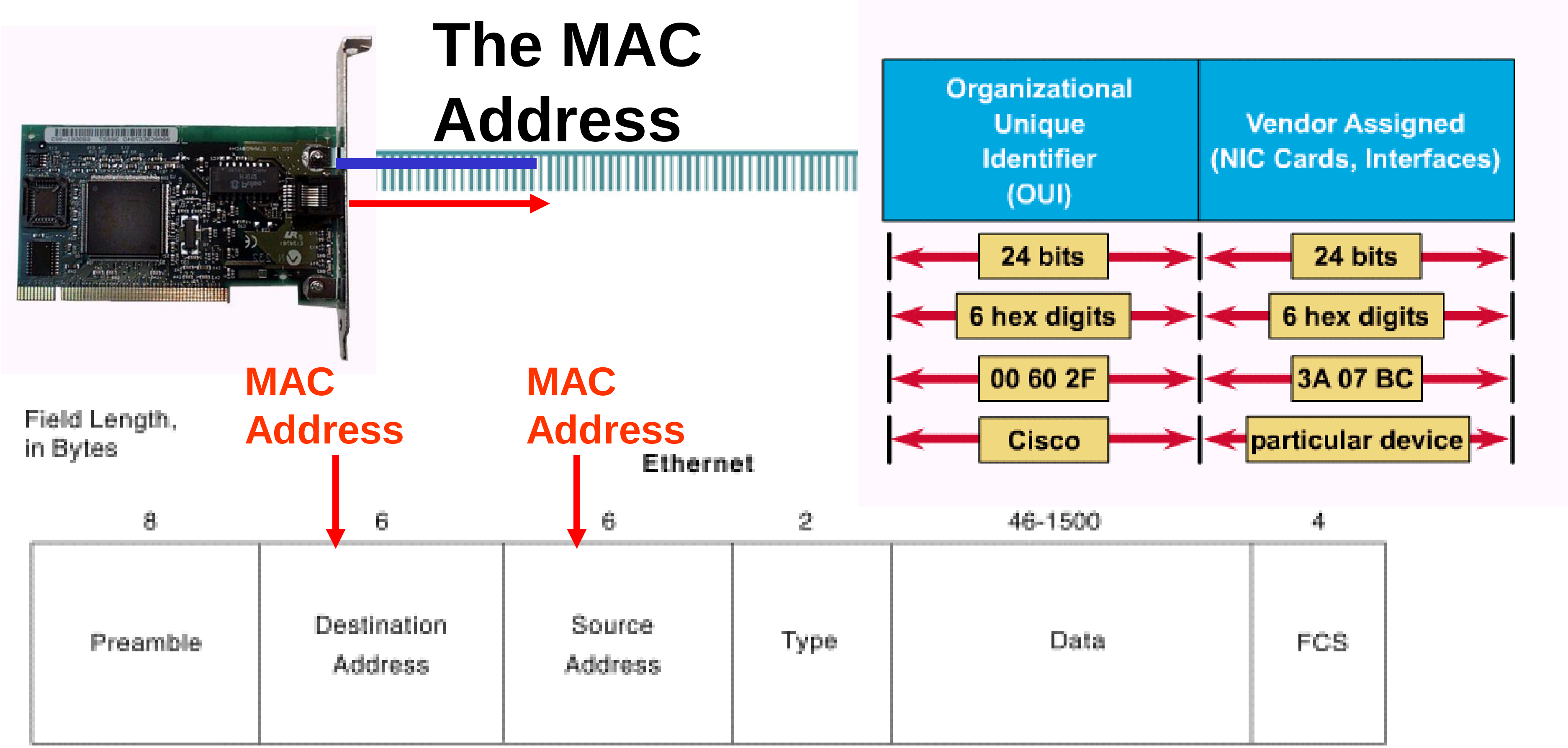
The MAC Address





- MAC addresses are:
  - **48 bits** in length
  - Expressed as **12 hexadecimal digits**.
  - The **first 6 hexadecimal digits**, which are administered by the IEEE, identify the manufacturer or vendor and thus comprise the ***Organizational Unique Identifier (OUI)***.
  - The remaining **6 hexadecimal digits** comprise the ***interface serial number***, or another value administered by the specific vendor.
- MAC addresses are sometimes referred to as ***burned-in addresses (BIAs)*** because they are burned into read-only memory (ROM) and are copied into random-access memory (RAM) when the NIC initializes

The MAC Address

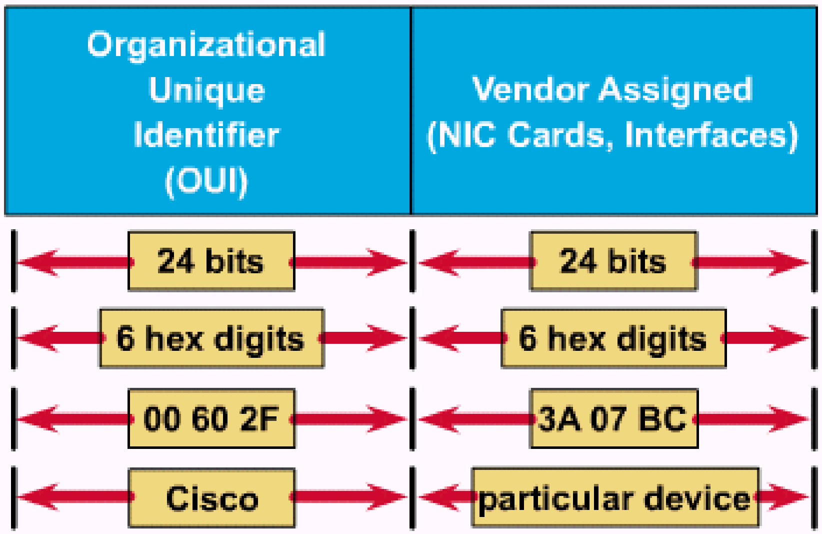


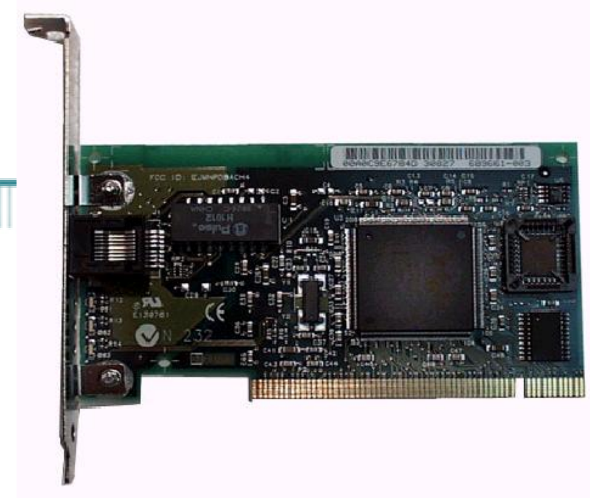
- The Ethernet protocol uses MAC addresses to identify the **source** of the Ethernet frame and the **destination** of the Ethernet frame.
- Whenever is computer sends an Ethernet frame, it includes the MAC address on its NIC as the Source “MAC” Address.
- We will learn later how it learns the Destination “MAC” Address.
- We will see how all of this works in a moment.

Decimal, Binary, Hex

Dec	Bin	Hex	Dec	Bin	Hex
0 =	0000 =	0	8 =	1000 =	8
1 =	0001 =	1	9 =	1001 =	9
2 =	0010 =	2	10 =	1010 =	A
3 =	0011 =	3	11 =	1011 =	B
4 =	0100 =	4	12 =	1100 =	C
5 =	0101 =	5	13 =	1101 =	D
6 =	0110 =	6	14 =	1110 =	E
7 =	0111 =	7	15 =	1111 =	F

MAC Address Format



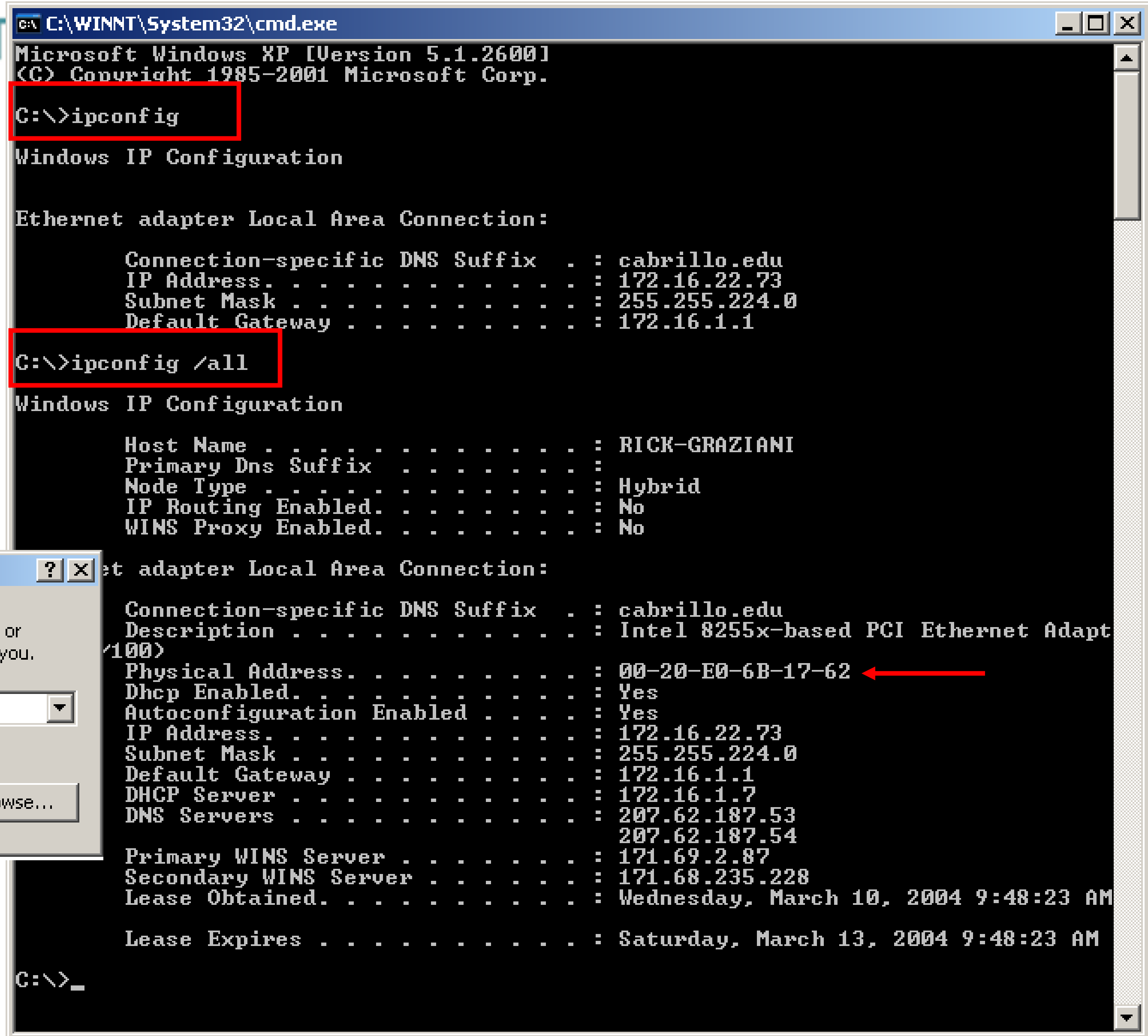


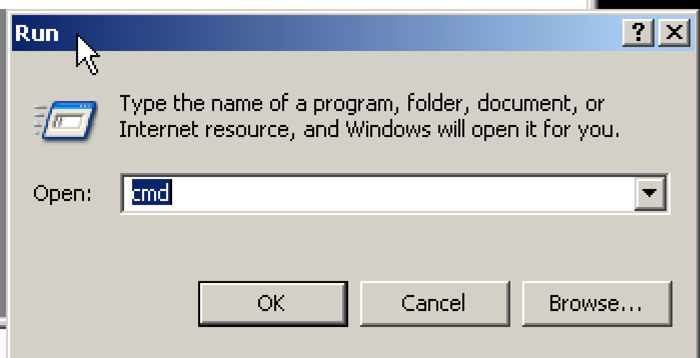
Dec	Bin	Hex	Dec	Bin	Hex
0	0000	0	8	1000	8
1	0001	1	9	1001	9
2	0010	2	10	1010	A
3	0011	3	11	1011	B
4	0100	4	12	1100	C
5	0101	5	13	1101	D
6	0110	6	14	1110	E
7	0111	7	15	1111	F

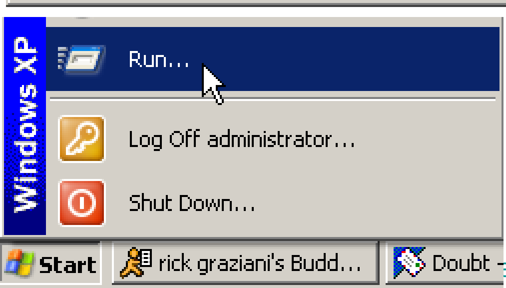
OUI **unique**

- An Intel MAC address: **00-20-E0**-**6B-17-62**
- 0000 0000 - 0010 0000 – 1110 0000 - 0110 1011 – 0001 0111 – 0110 0010
- IEEE OUI FAQs: http://standards.ieee.org/faqs/OUI.html

What is the Address on my NIC?







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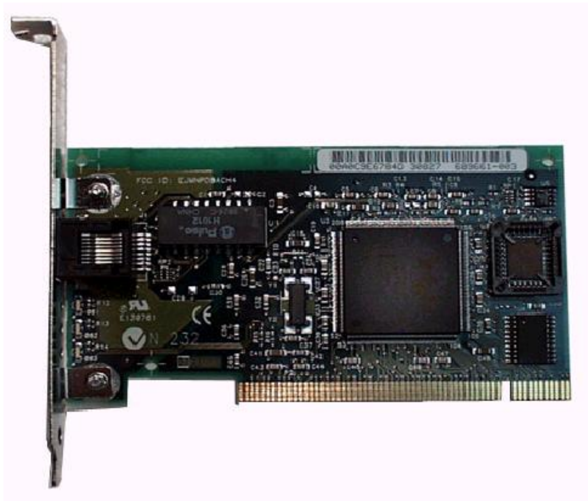
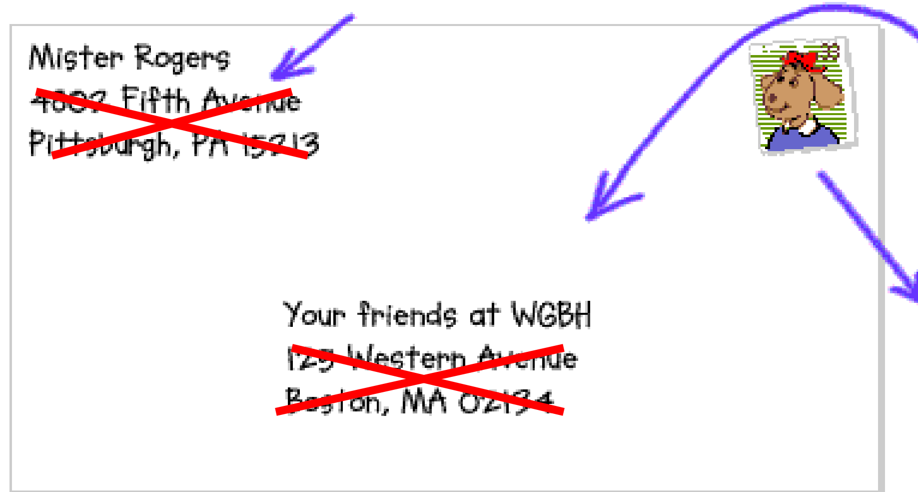
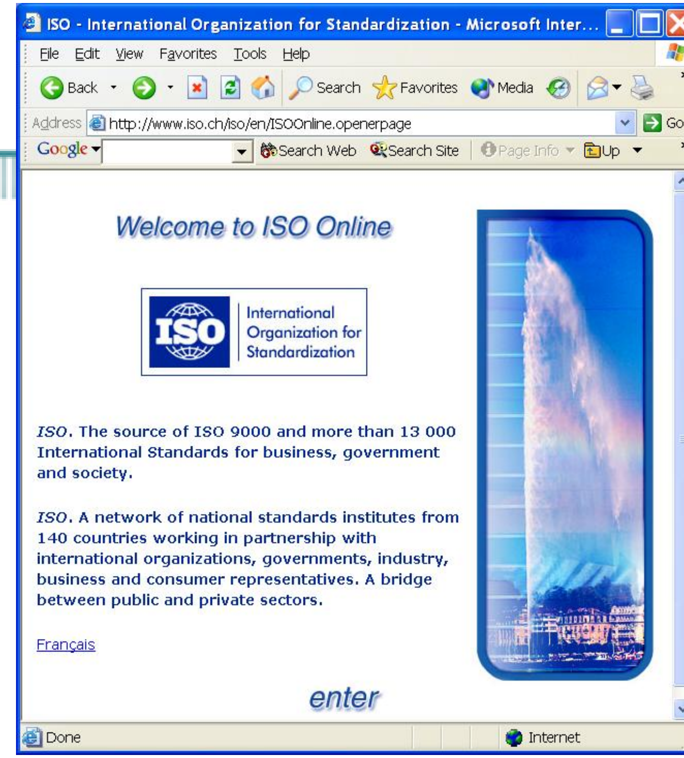
MAC Addresses Are Flat





- MAC addresses provide a way for computers to identify themselves.
- They give hosts a permanent, unique name.
- The number of possible MAC addresses is 16^12 (or over 2 trillion!).
- MAC addresses do have one major **disadvantage**:
  - They have **no structure**, and is considered flat address space.
  - Like using just a name when sending a letter instead of a structured address.

A brief detour…
Matching Ethernet to the OSI Model



- The ***International Organization for Standardization*** **(*ISO*)** released the Open System Interconnection **(*OSI*)** *reference model* in 1984, was the descriptive scheme they created.
- **"*ISO*. A network of national standards institutes from 140 countries working in partnership with international organizations, governments, industry, business and consumer representatives. A bridge between public and private sectors."** www.iso.ch

ISO and the OSI Model

- “According to ISO, "ISO" is not an abbreviation. It is a word, derived from the Greek ***isos***, meaning "**equal**", which is the root for the prefix "iso-" that occurs in a host of terms, such as "isometric" (of equal measure or dimensions) and "isonomy" (equality of laws, or of people before the law).
- The name ISO is used around the world to denote the organization, thus avoiding the assortment of abbreviations that would result from the translation of "International Organization for Standardization" into the different national languages of members.
- Whatever the country, the short form of the organization's name is always ISO.” www.whatis.com

OSI Model – Make more sense later

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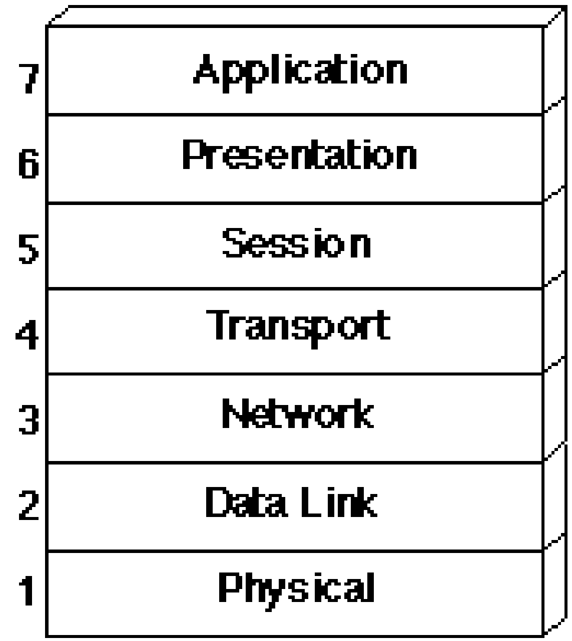
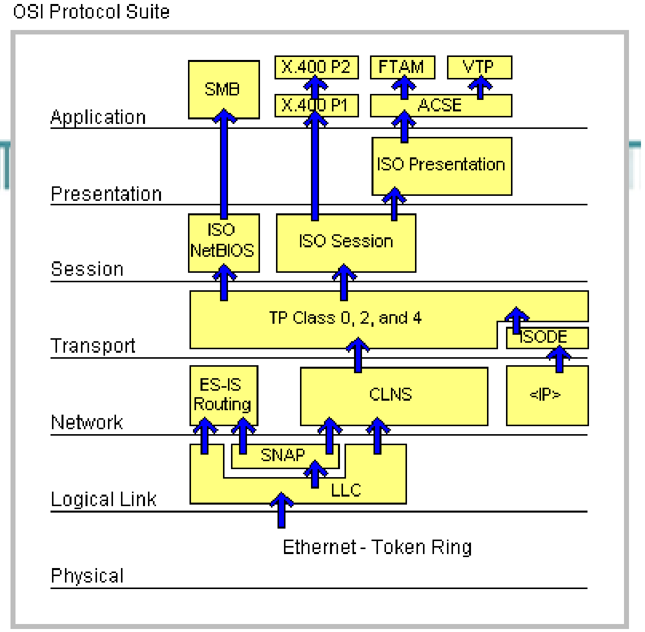
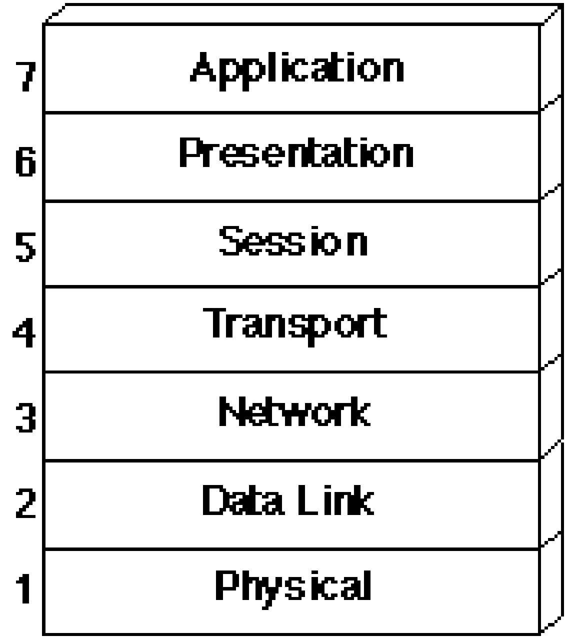
- It breaks network communication into smaller, more manageable parts.
- It standardizes network components to allow multiple vendor development and support.
- It allows different types of network hardware and software to communicate with each other.
- It prevents changes in one layer from affecting other layers.
- It divides network communication into smaller parts to make learning it easier to understand.



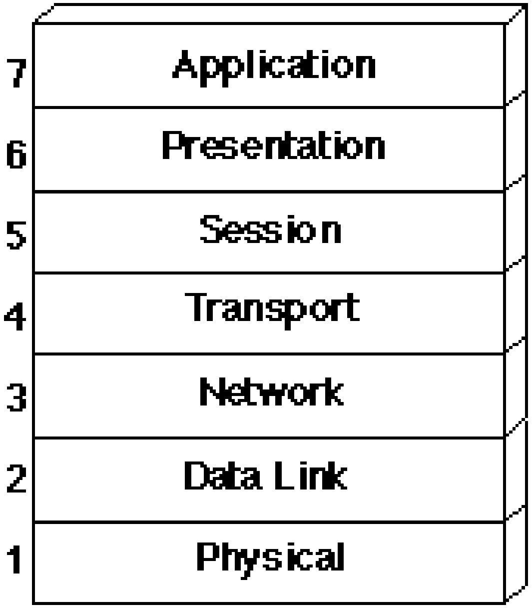
OSI Model





- **OSI** (Open Systems Interface) was released as a **suite of protocols** to be used as the Internet standard.
- However, **TCP/IP** became the de facto standard.
- The OSI reference model is the primary model for network communications.
- Although there are other models in existence, most network vendors, today, relate their products to the OSI reference model, especially when they want to educate users on the use of their products.

OSI Model

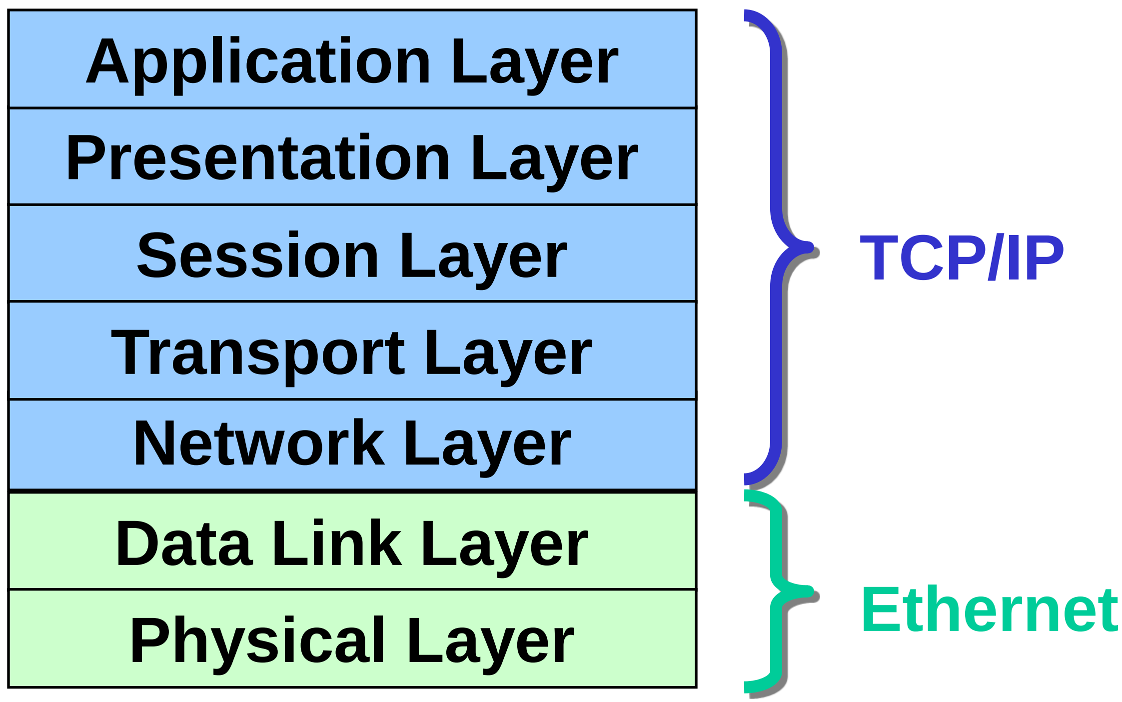


The use of this model can be confusing and will become clearer later!

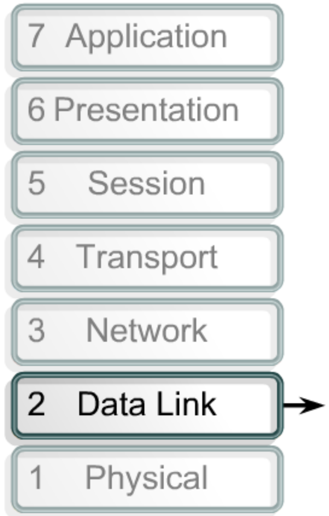
- The **OSI reference model** allows you to
  - view the network functions that occur at each layer
  - a framework that you can use to understand how information travels throughout a network.
  - understand, visualize, and troubleshoot the sending and receiving data on a network
  - visualize how information, or data packets, travels from application programs, through a network medium (e.g. wires, etc.), to another application program that is located in another computer on a network, even if the sender and receiver have different types of network media
- Note: The Application Layer of the OSI model refers to networking applications, and not user applications.

Ethernet and TCP/IP

Ethernet & TCP/IP are the most pervasive LAN protocols, and are often used together.

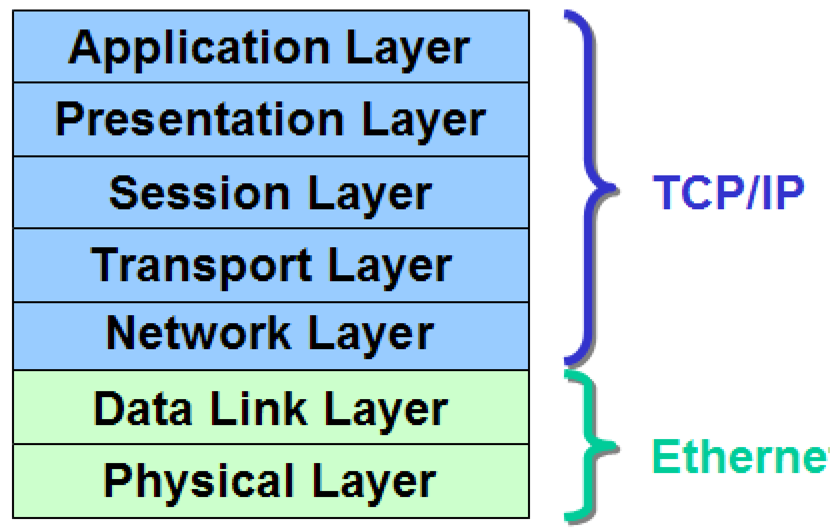


Ethernet and OSI Model



Direct Link Control, Access to Media
- Provides reliable transfer of data across media
- Physical addressing, network topology, error notification, flow control

Binary Transmission
- Wires, connectors, voltages, data rates



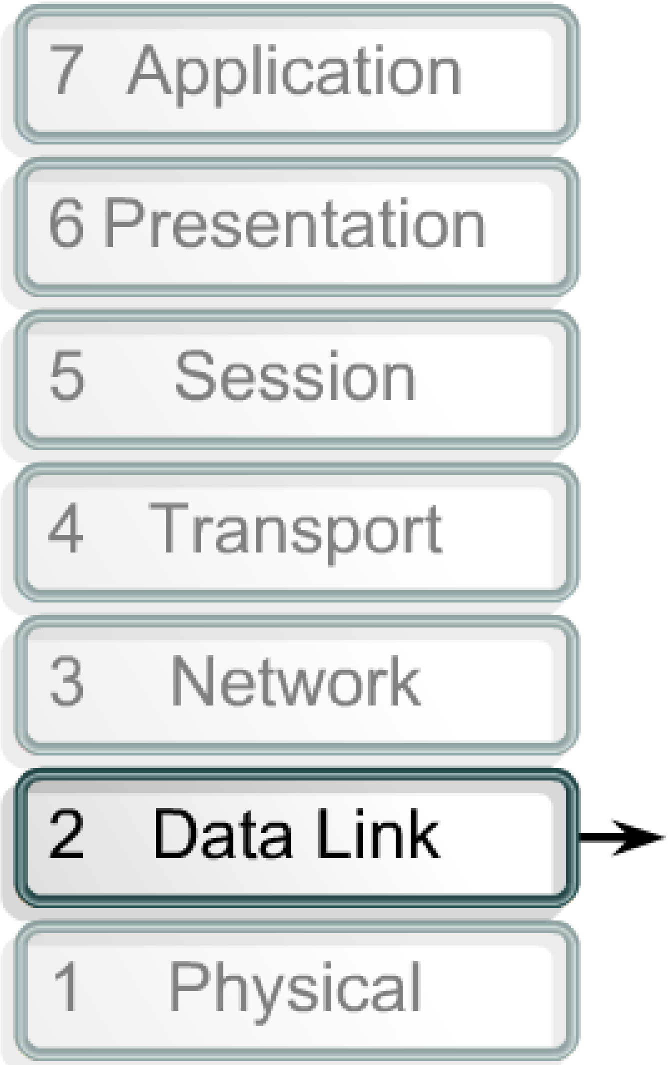
OSI Layer 1 – Physical Layer

- The physical layer defines the electrical, mechanical, procedural, and functional specifications for activating, maintaining, and deactivating the physical link between end systems.
- Signals, network media (cables, wireless, …), layer 1 devices
- Layer 1 devices include:
  - Repeaters
  - Hubs

Binary Transmission
• Wires, connectors, voltages, data rates

OSI Layer 2 – Data Link Layer

- The data link layer provides reliable transit of data across a physical link. In so doing, the data link layer is concerned with physical (as opposed to logical) addressing, network topology, network access, error notification, ordered delivery of frames, and flow control.
- **Frames** and Layer 2 protocols
- Layer 2 devices include:
  - Switches
  - Bridges



Direct Link Control, Access to Media

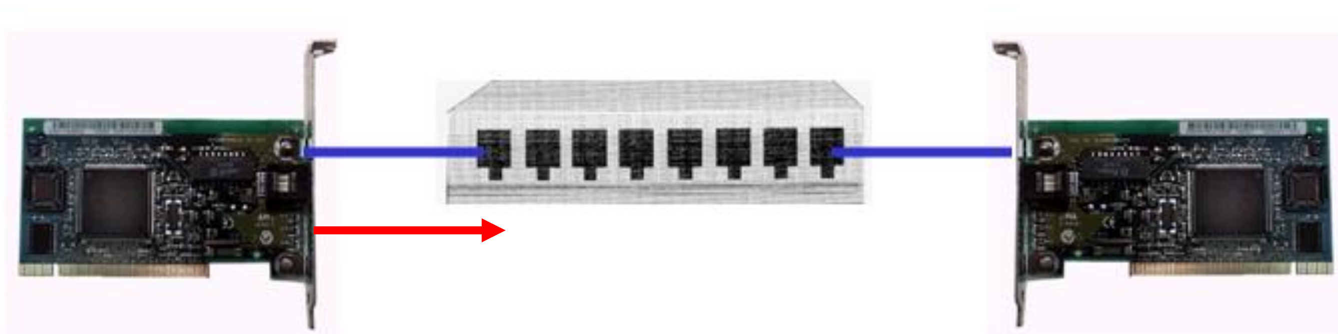
- Provides reliable transfer of data across media
- Physical addressing, network topology, error notification, flow control

Generic Data Link Frame

Field Length, in Bytes

Ethernet

8	6	6	2	46-1500	4
Preamble	Destination Address	Source Address	Type	Data	FCS



- A message is “**framed**” (layer 2) and transmitted on the cable (layer 1) by the Ethernet NIC.
- Framing provides order, or structure, to the stream of bits, bitstream.
- Let’s not worry about the “data” right now.

Bringing it all together…

- Let's pause here for a moment and figure all of this out!

- Let's bring the following together:
  - Ethernet Frames and MAC Addresses
  - Sending and receiving Ethernet frames on a bus
  - CSMA/CD
  - Sending and receiving Ethernet frames via a hub
  - Sending and receiving Ethernet frames via a switch

Serial vs Multiaccess Network

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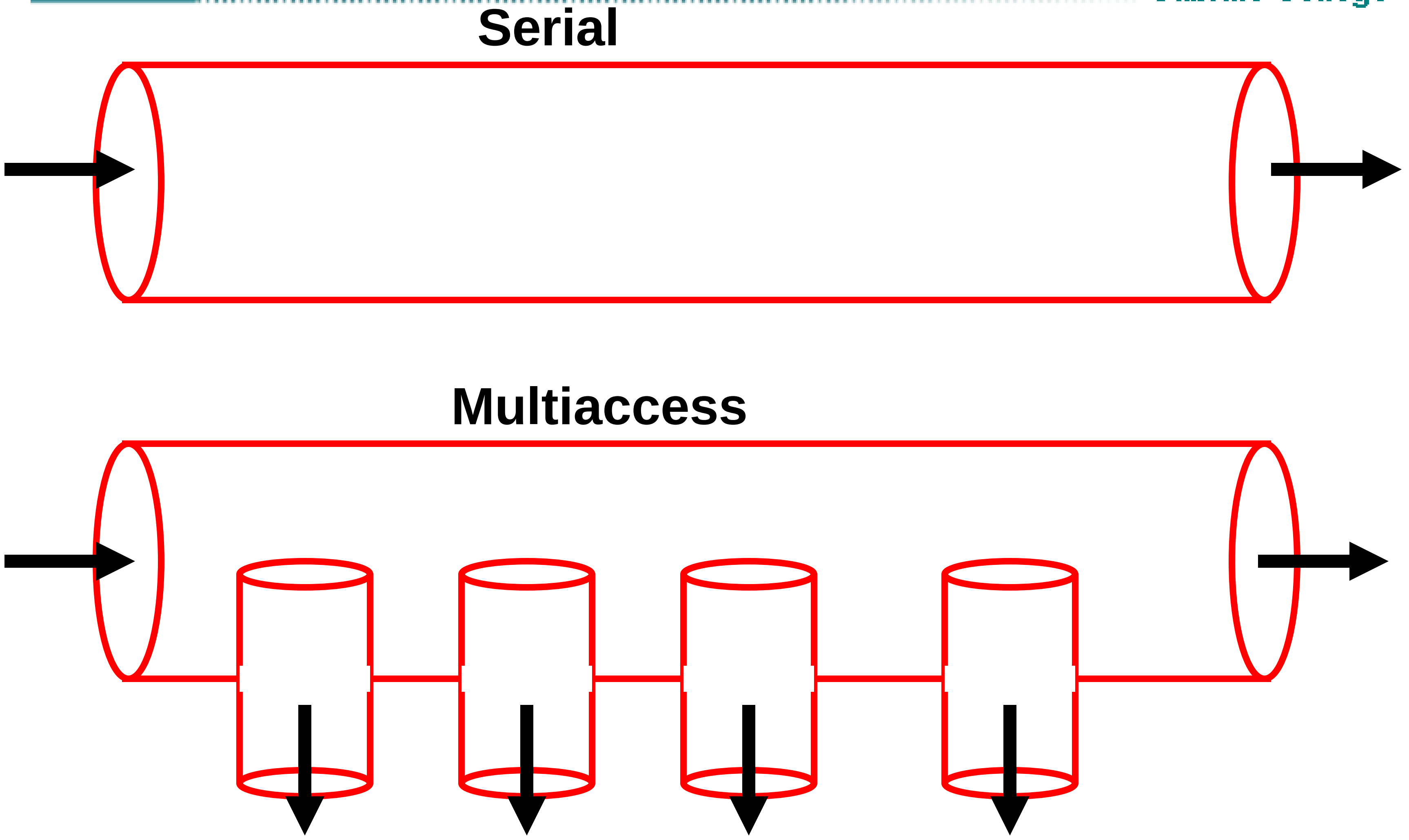
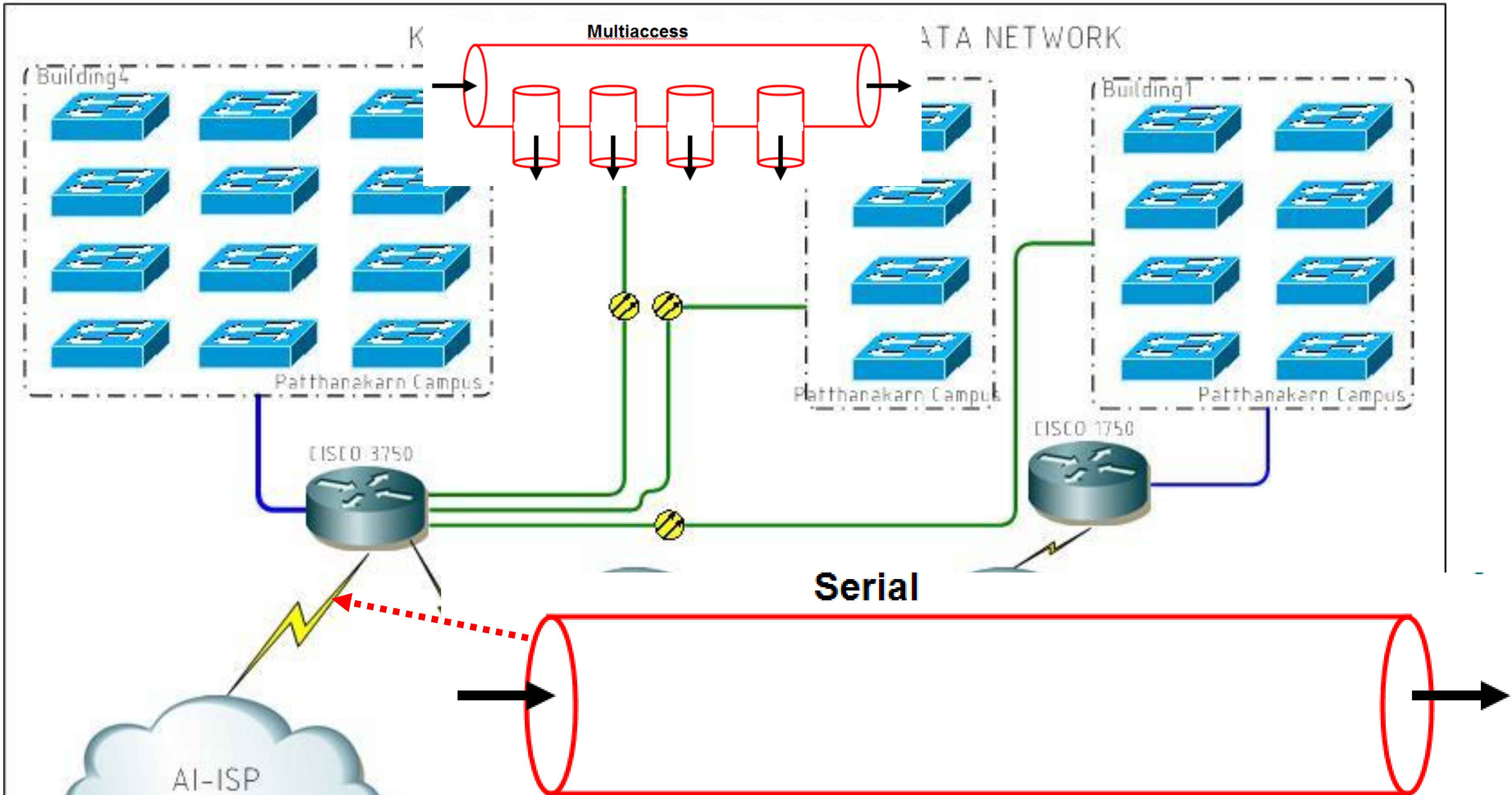
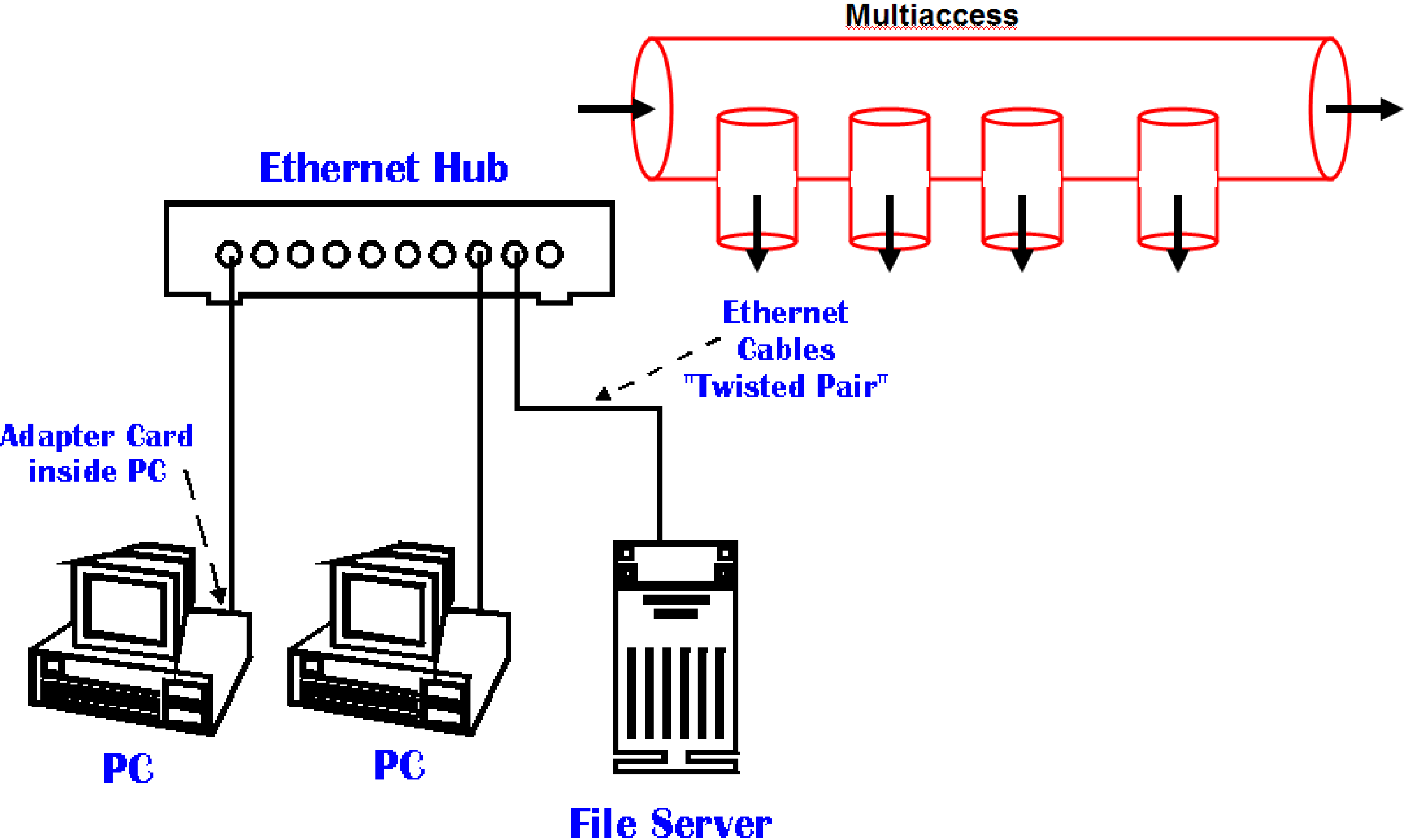


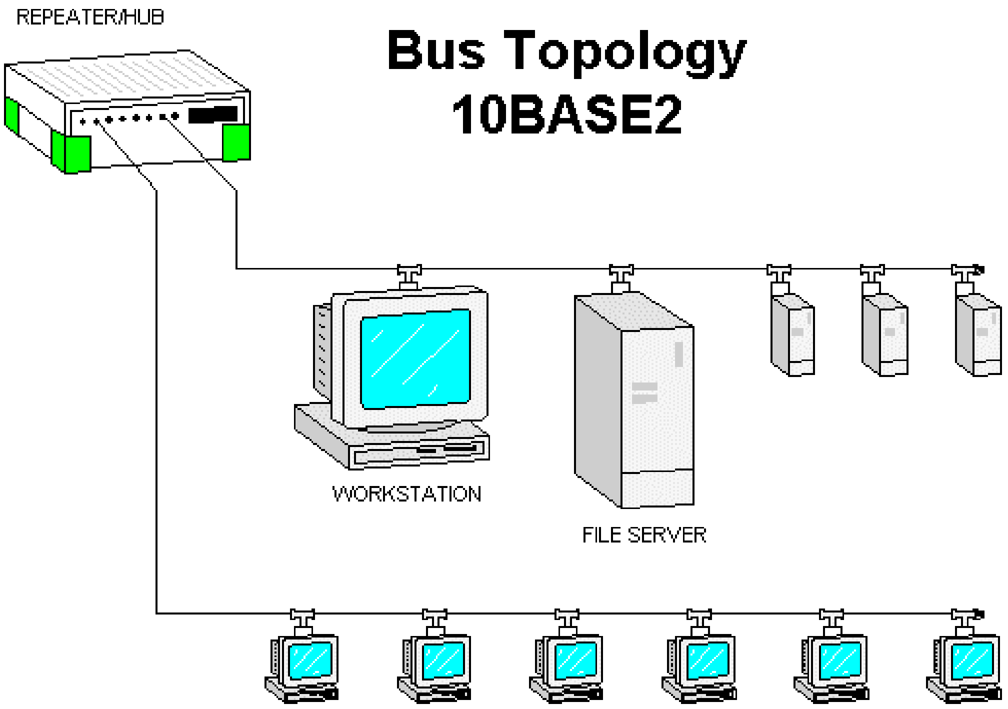


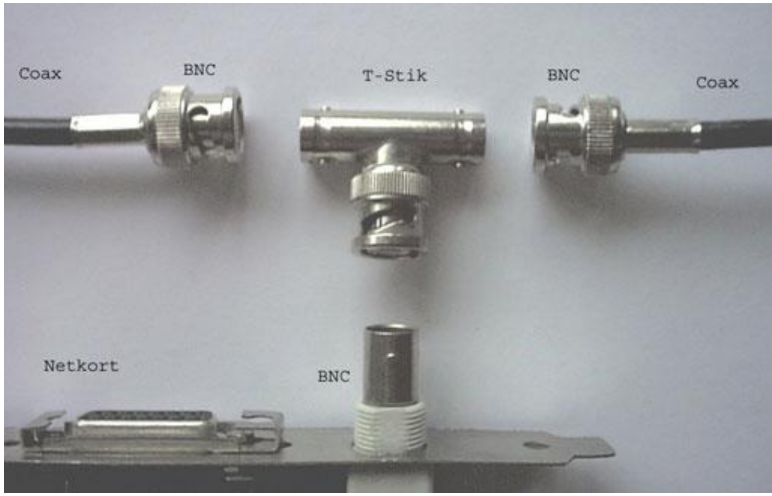
- Point-to-Point Serial networks
  - Usually connection between only two devices, such as two routers.
  - Point-to-Point Serial protocols include ISDN, PPP, HDLC, T1, T3, etc.

Ethernet: Multiaccess Network



Bus Topology



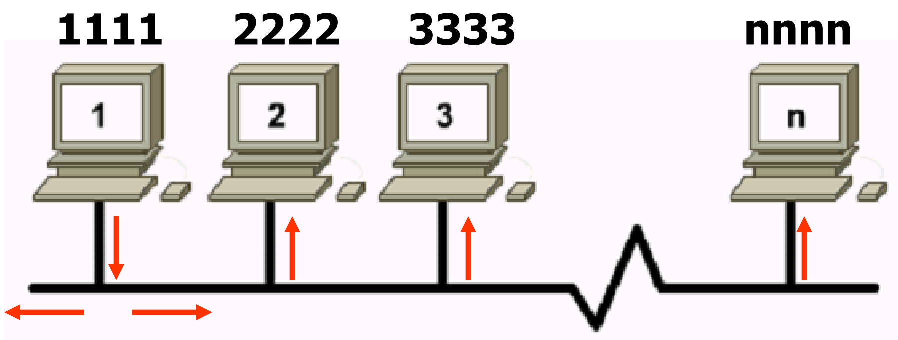


A <u>bus topology</u> uses a single backbone segment (length of cable) that all the hosts connect to directly.

Original Ethernet used a bus topology.

By the way, Ethernet hubs work the same as a “bus”.

Sending and receiving Ethernet frames on a bus



Abbreviated MAC Addresses

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC

3333 1111

- When an Ethernet frame is sent out on the "bus" all devices on the bus receive it.
- What do they do with it?

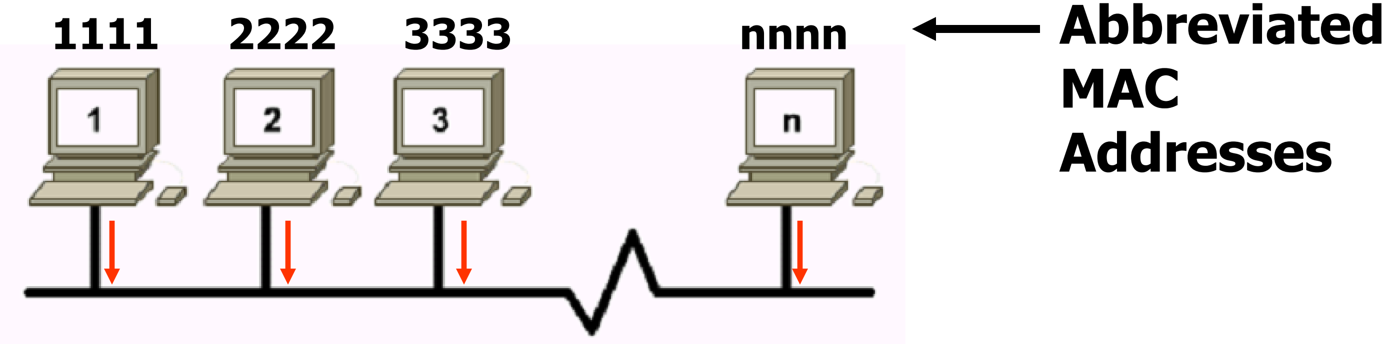
Sending and receiving Ethernet frames on a bus

Abbreviated MAC Addresses

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	3333	1111				

- When information (frame) is transmitted, every **PC/NIC** on the shared media **copies** part of the transmitted frame to see if the **destination address** matches the address of the NIC.
- If there is a **match**, the rest of the frame is **copied**
- If there is **NOT** a match the rest of the frame is **ignored**.
  - Unless you are running a protocol analyzer program such as Ethereal.

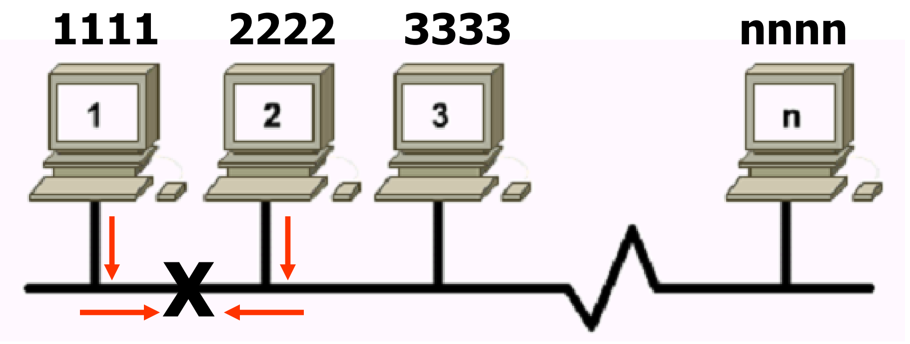
Sending and receiving Ethernet frames on a bus



Preamble	Destination Address	Source Address	Type	Data	Pad	CRC

- So, what happens when multiple computers try to transmit at the same time?

Sending and receiving Ethernet frames on a bus



Abbreviated MAC Addresses

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC

<u>Collision</u>!

Access Methods

Two common types of access methods for LANs include

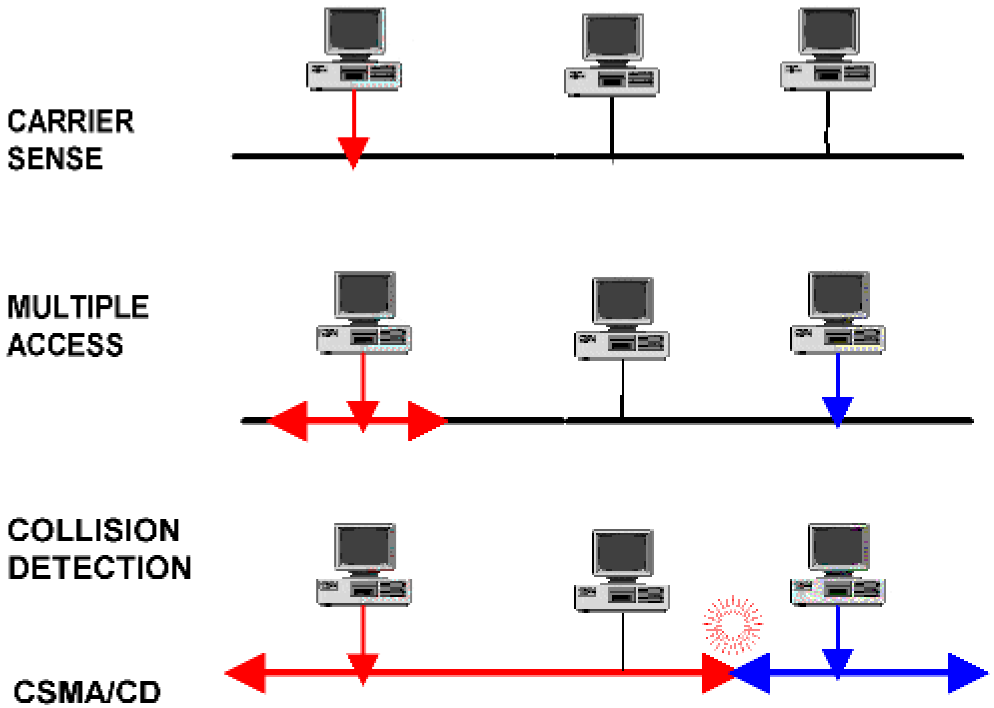
- **Non-Deterministic**: Contention methods (Ethernet, IEEE 802.3)
  - Only one signal can be on a network segment at one time.
  - Collisions are a normal occurrence on an Ethernet/802.3 LAN

- **Deterministic**: Token Passing (Token Ring)
  - more later

CSMA/CD (Carrier Sense Multiple Access with Collision Detection)

CSMA/CD Common contention method used with Ethernet and IEEE 802.3

- "Let everyone have access whenever they want and we will work it out somehow."

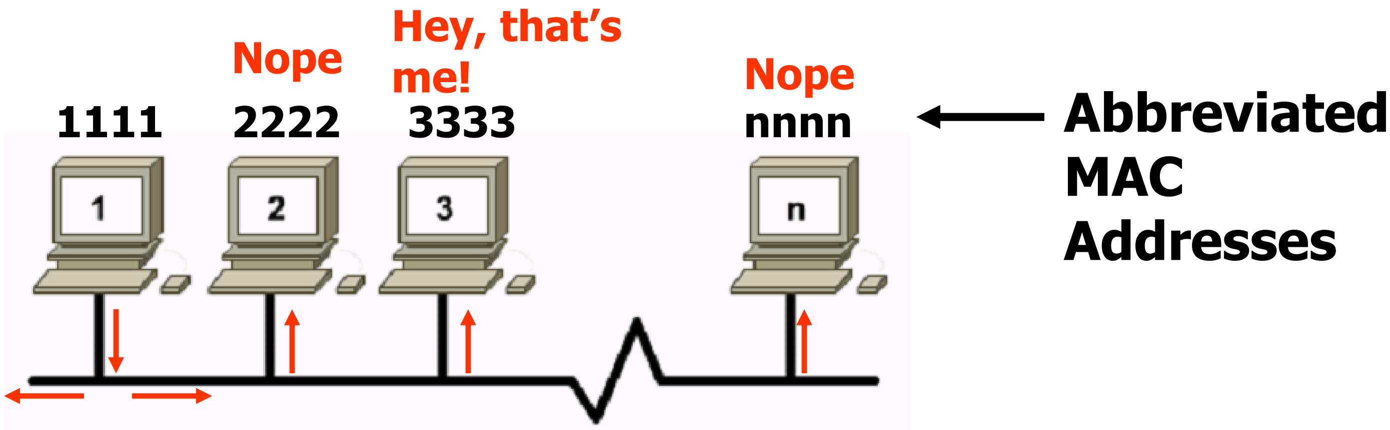


CSMA/CD and Collisions

CSMA/CD (Carrier Sense Multiple Access with Collision Detection)

- **Listens** to the network's shared media to see if any other users on "on the line" by trying to sense a neutral electrical signal or carrier.
- If no transmission is sensed, then *multiple access* **allows anyone onto the media** without any further permission required.
- If two PCs detect a neutral signal and access the shared media at the exact same time, a ***collision*** occurs and is *detected*.
- The PCs sense the collision by being unable to deliver the entire frame (coming soon) onto the network. *(This is why there are minimum frame lengths along with cable distance and speed limitations. This includes the 5-4-3 rule.)*
- When a collision occurs, a **jamming signal** is sent out by the first PC to detect the collision.
- Using either a **priority or random backoff scheme**, the PCs wait certain amount of time before retransmitting.
- If collisions continue to occur, the PCs random interval is doubled, lessening the chances of a collision.

CSMA/CD and Collisions



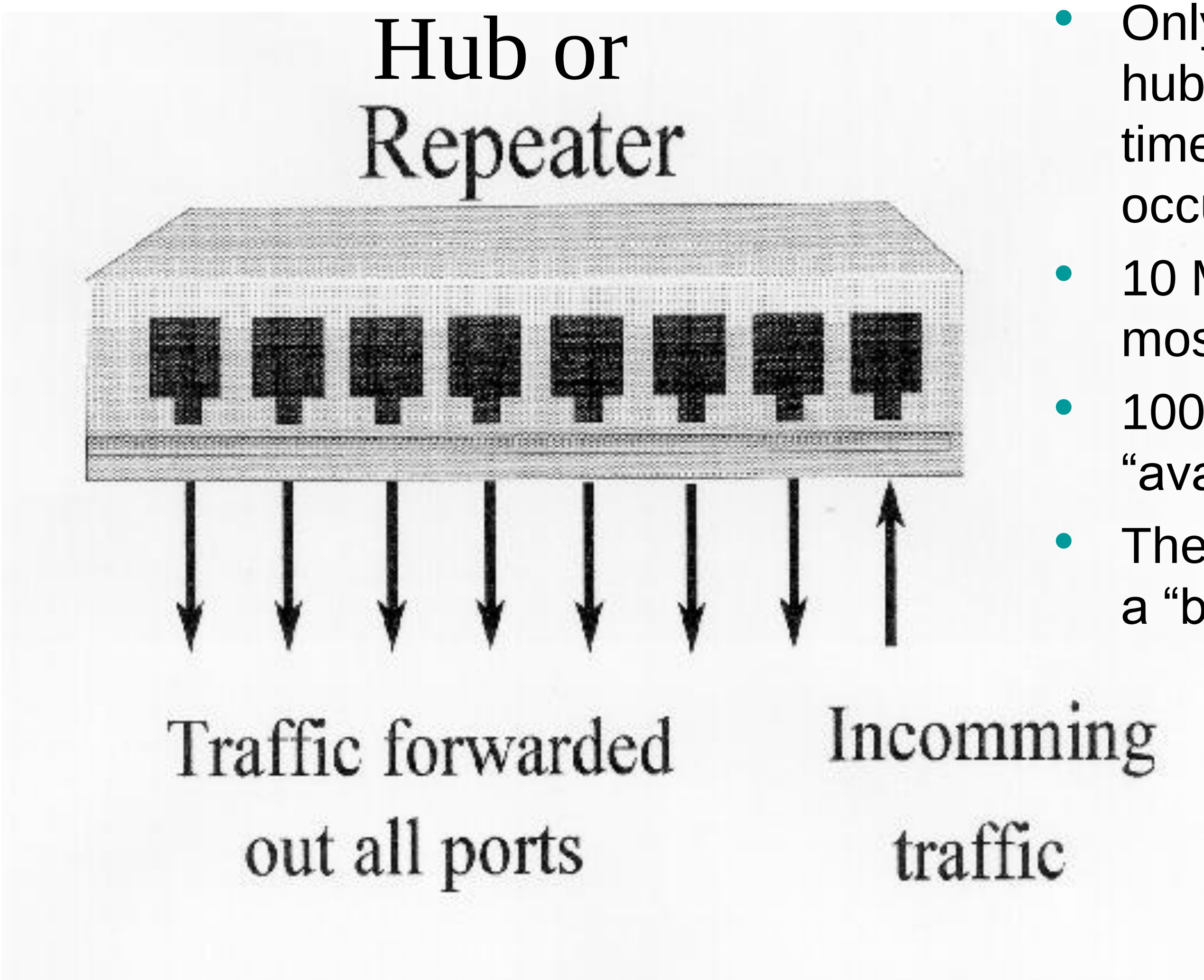
Notice the location of the DA!

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	3333	1111				

And as we said,

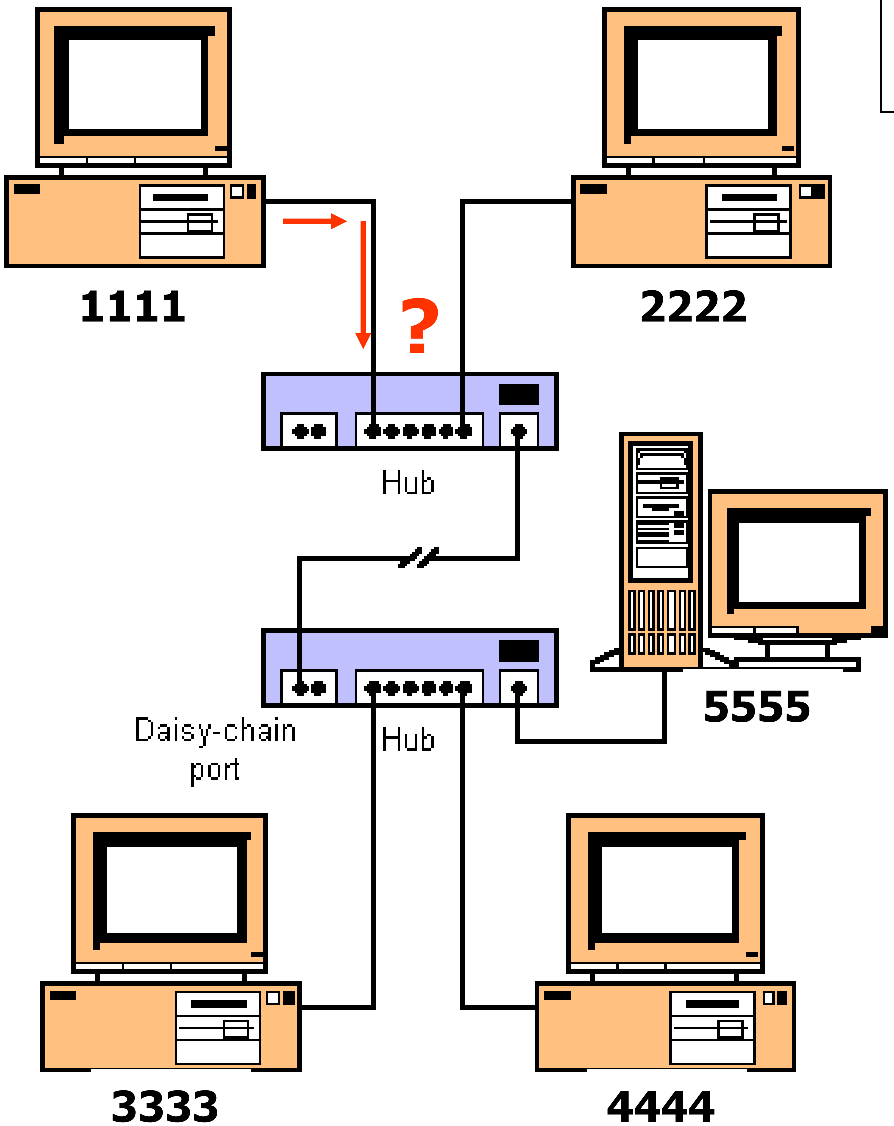
- When information (frame) is transmitted, every PC/NIC on the shared media copies part of the transmitted frame to see if the destination address matches the address of the NIC.
- If there is a match, the rest of the frame is copied
- If there is NOT a match the rest of the frame is ignored.

Sending and receiving Ethernet frames via a hub



- Only one device on the hub can communicate at a time, otherwise collisions occur.
- 10 Mbps ports are the most common.
- 100/1000 Mbps also "available".
- The hub acts the same as a "bus".

Sending and receiving Ethernet frames via a hub



Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	3333	1111				

- So, what does a hub do when it receives information?
- A **hub** is nothing more than a multiport repeater.

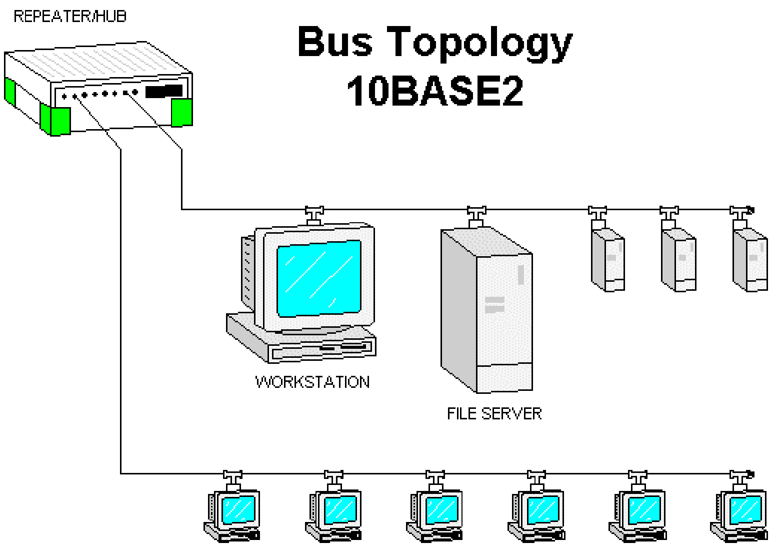
Another detour…
OSI Layer 1 – Physical Layer

Binary Transmission
• Wires, connectors, voltages, data rates

- The physical layer defines the electrical, mechanical, procedural, and functional specifications for activating, maintaining, and deactivating the physical link between end systems.
- Signals, network media (cables, wireless, …), layer 1 devices
- Layer 1 devices include:
  - Repeaters
  - Hubs

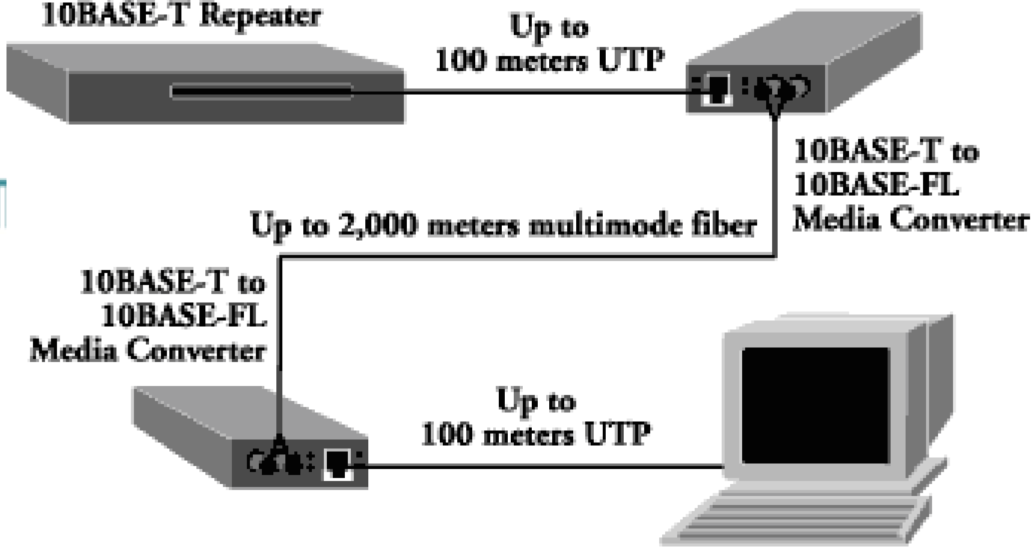
Repeaters

Medium	Max Distance
Twisted Pair	100 meters
Coaxial Cable	185/500 meters
Fiber Optic	2+ kilometers



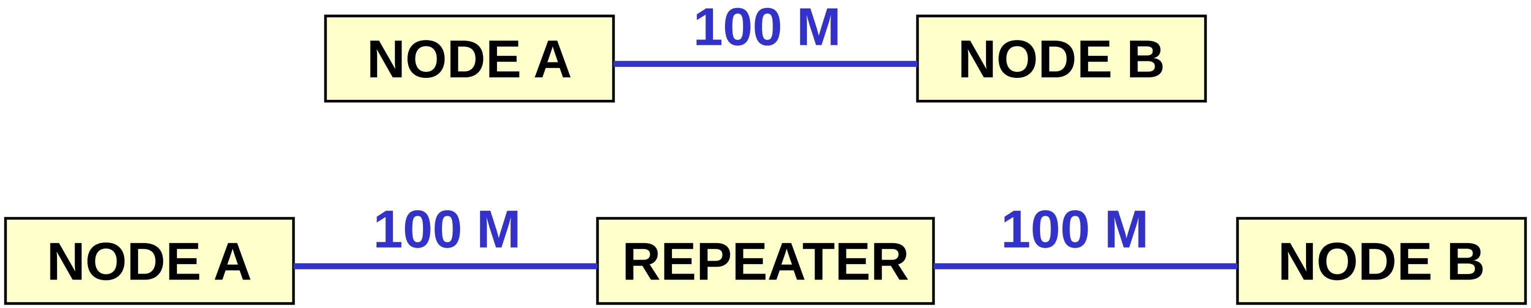
- Signals can only travel so far through media before they weaken, and become garbled.
- This weakening of signals is called **attenuation**.
- Attenuation increases when:
  - Media distances are lengthened
  - Nodes are added to the media

The Repeater



- Repeaters are Layer 1 internetwork devices used to combat attenuation.
- Repeaters:
  - take in weakened signals
  - clean them up
  - <u>regenerate</u> them
  - send them on their way along the network

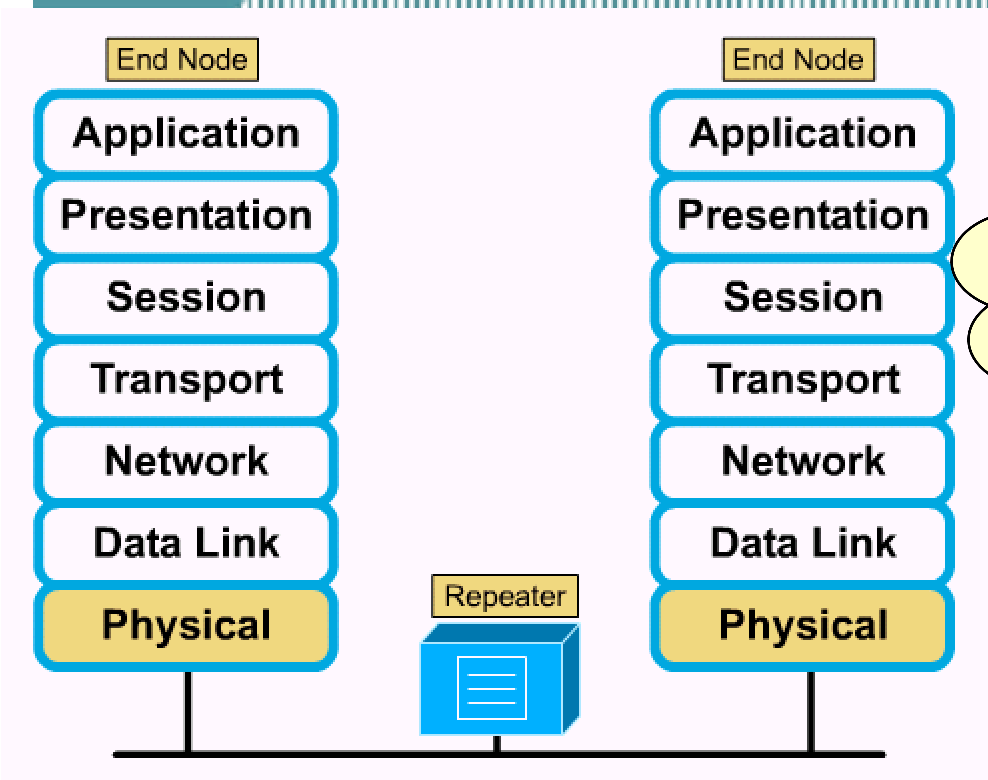
Repeaters Extend Distances



By using repeaters, the distance over which a network can operate is extended.

Example: 10Base-T (a wiring standard) is allowed to run 100 meters. One repeater can double this distance to 200 meters!

Repeater: Layer 1 Device



Signal come in … signal go out. (after I amplify it)

- **Repeaters** are <u>Layer 1</u> devices.
- They do **NOT** look at Layer 2, Data Link (MAC, Ethernet) addresses or Layer 3, IP Addresses.

Hub

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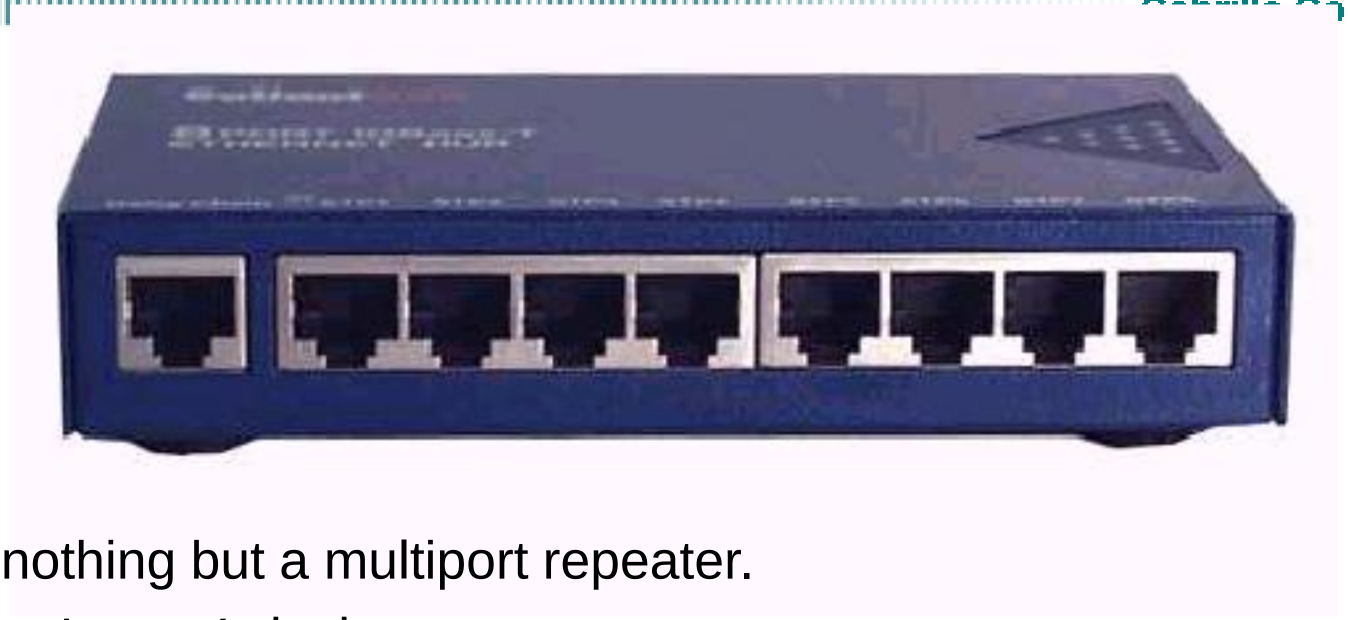

- **Hub** is nothing but a multiport repeater.
- Hubs are Layer 1 devices.
- Data that comes in one port is sent out all other ports, except for the port it came in on.

Hubs are sometimes called

- Ethernet concentrators
- Multiport repeaters
- In Token Ring nets, Multi-station Access Units (MAU or MSAU)

Hub: Layer 1 Device

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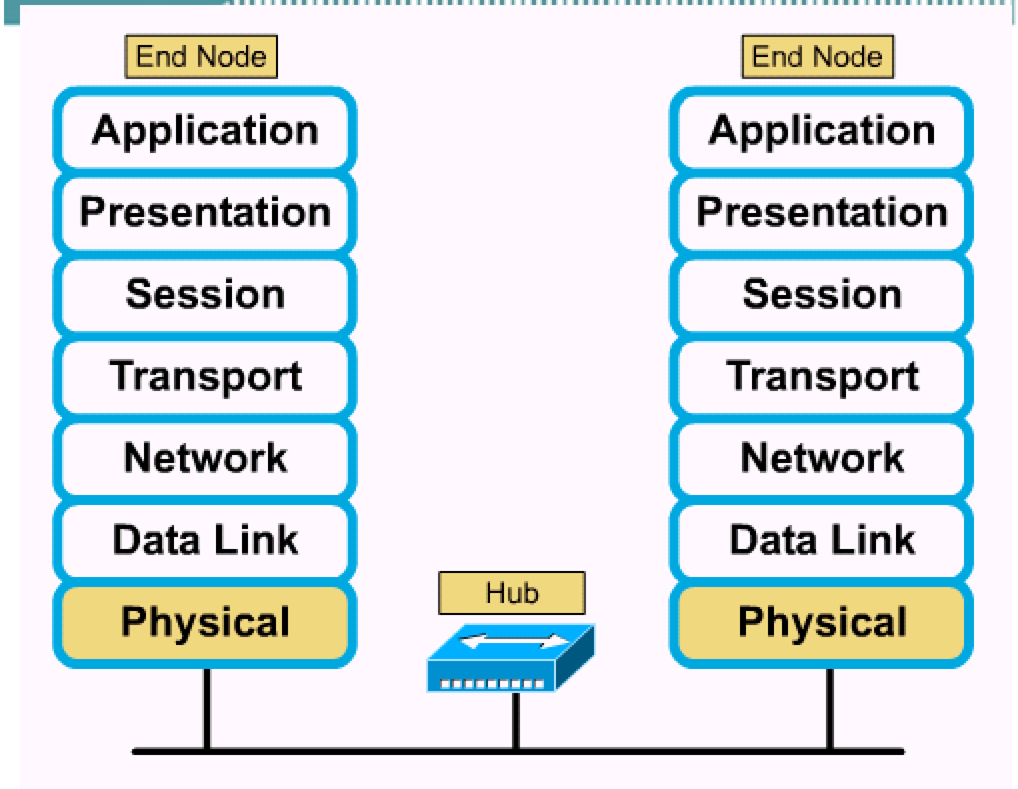
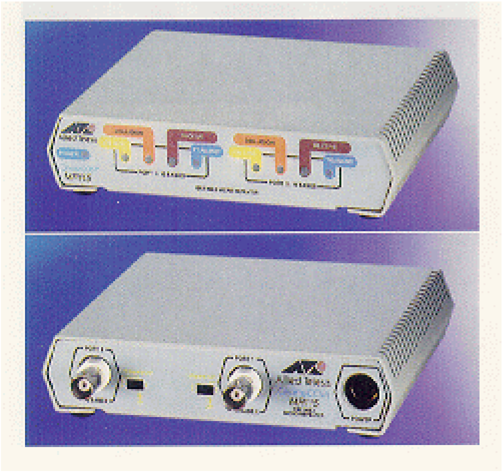
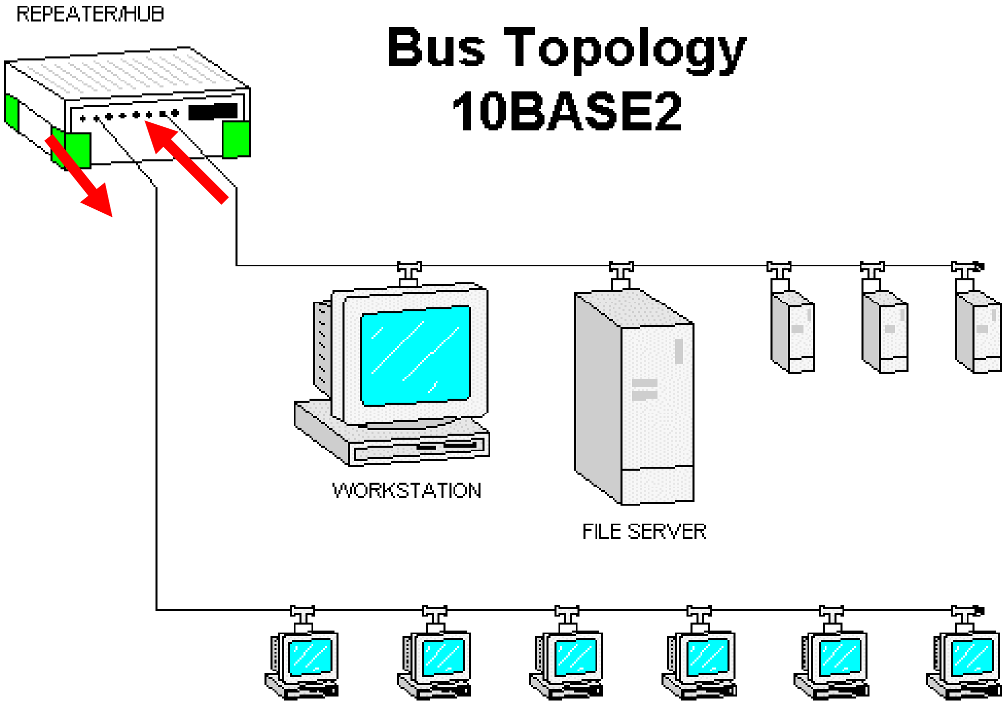


- Hubs are Layer 1 devices.
- They do **NOT** look at Layer 2, Data Link (MAC, Ethernet) addresses or Layer 3, IP Addresses.

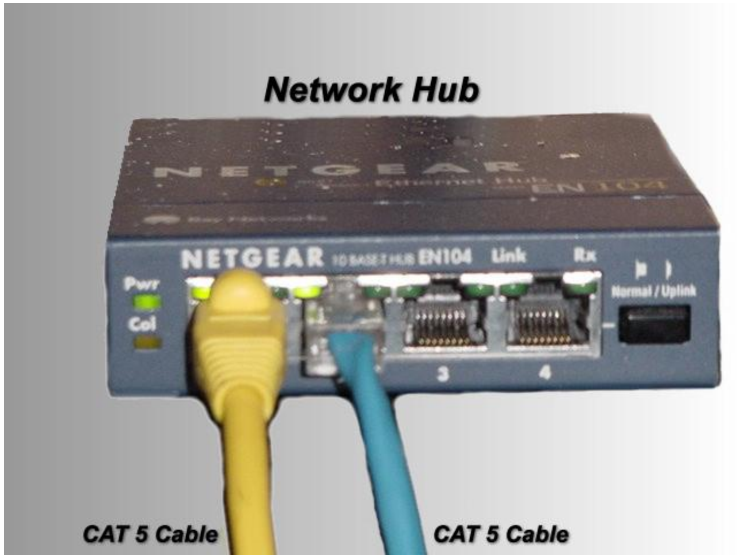
Repeaters

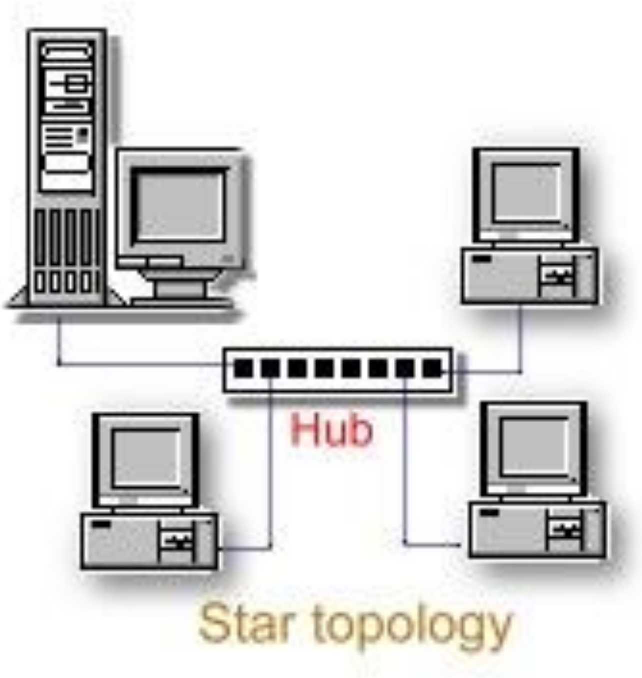




- In the “old days”, repeaters were typically used to extend the size or length of a **bus-topology** network.
- Repeaters take a signal in on one end and regenerate that signal out the other end.
- In most networks (LANs), **repeaters** have been replaced by **hubs**, which have been mostly replaced by **switches**.
- MORE LATER!

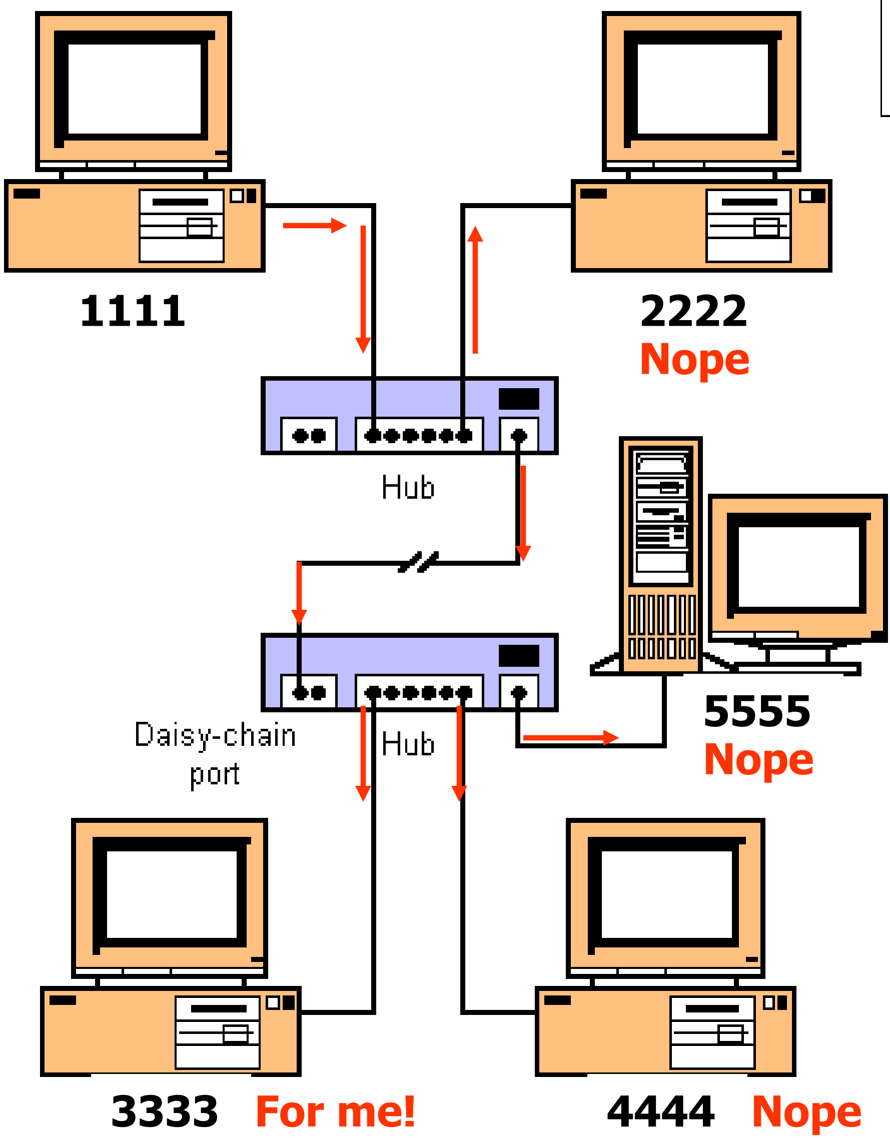
Hubs





- Hubs allow computers and other network devices to communicate with each other, and use a **<u>star topology</u>**.
- Like a repeater, a hub **regenerates** the signal.
- Hubs have the same disadvantage as a repeater, anything it receives on one port, it **FLOODS** out all other ports.
- Wherever possible, hubs should be replace by **switches**.
- More LATER!

Sending and receiving Ethernet frames via a hub

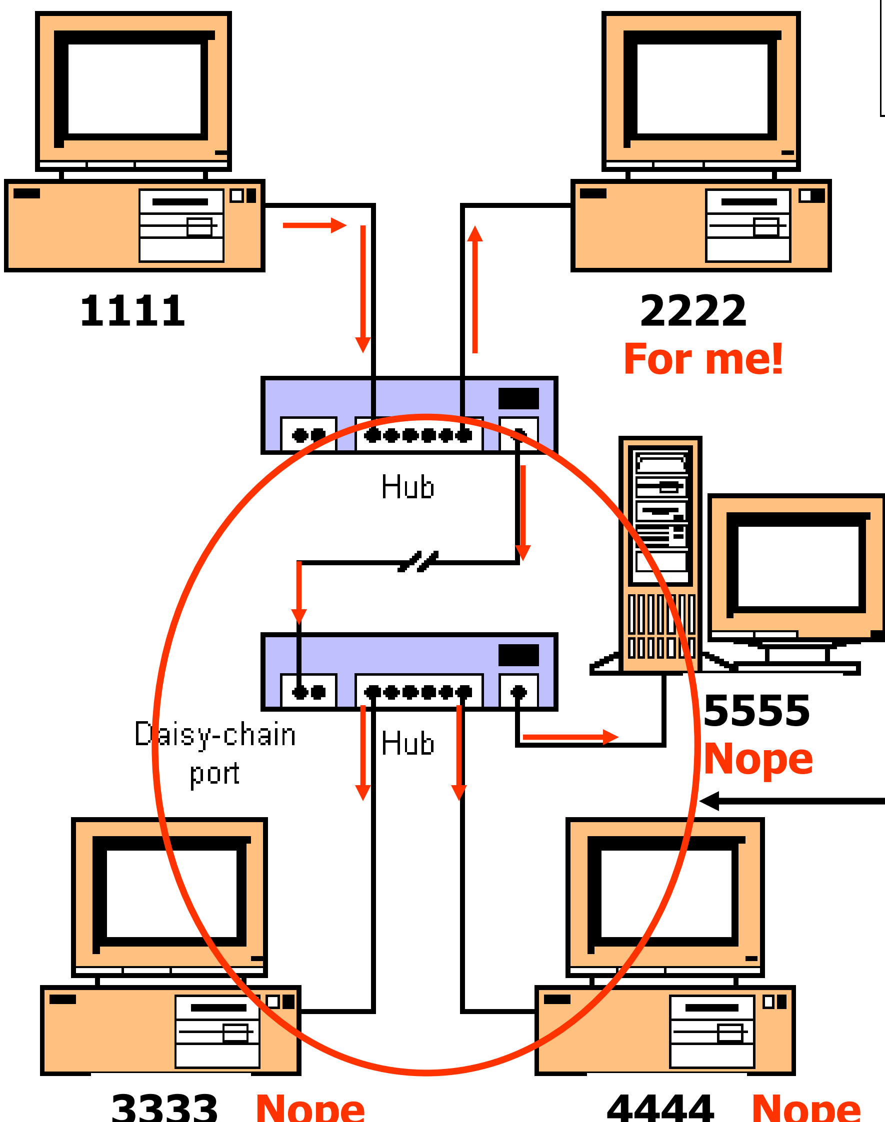


Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	3333	1111				

- The hub will **flood** it out all ports except for the incoming port.
- Hub is a layer 1 device.
- A hub does NOT look at layer 2 addresses, so it is fast in transmitting data.
- **Disadvantage** with hubs: A hub or series of hubs is a <u>single **collision domain**</u> (coming)
- A collision will occur if any two or more devices transmit at the same time within the collision domain.

Sending and receiving Ethernet frames via a hub

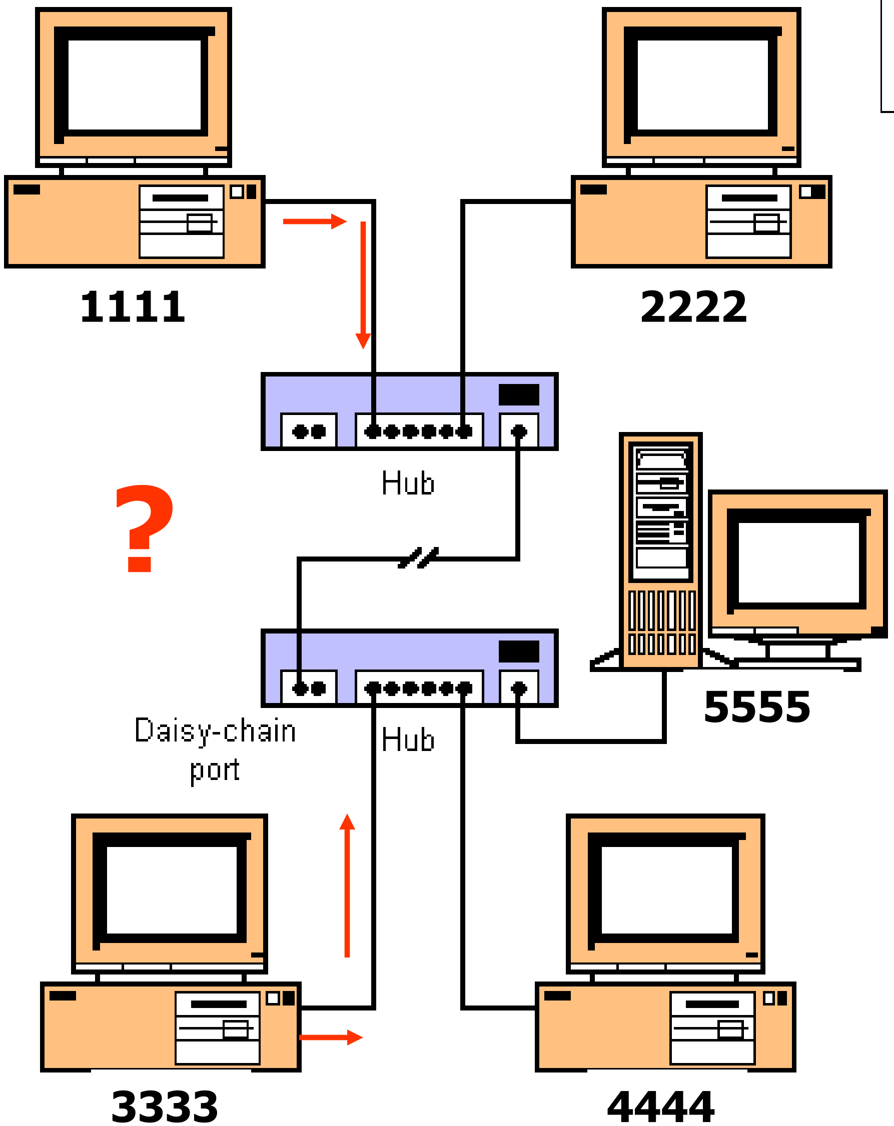
Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	2222	1111				



- Another disadvantage with hubs is that is take up unnecessary bandwidth on other links.

Wasted bandwidth

Sending and receiving Ethernet frames via a hub

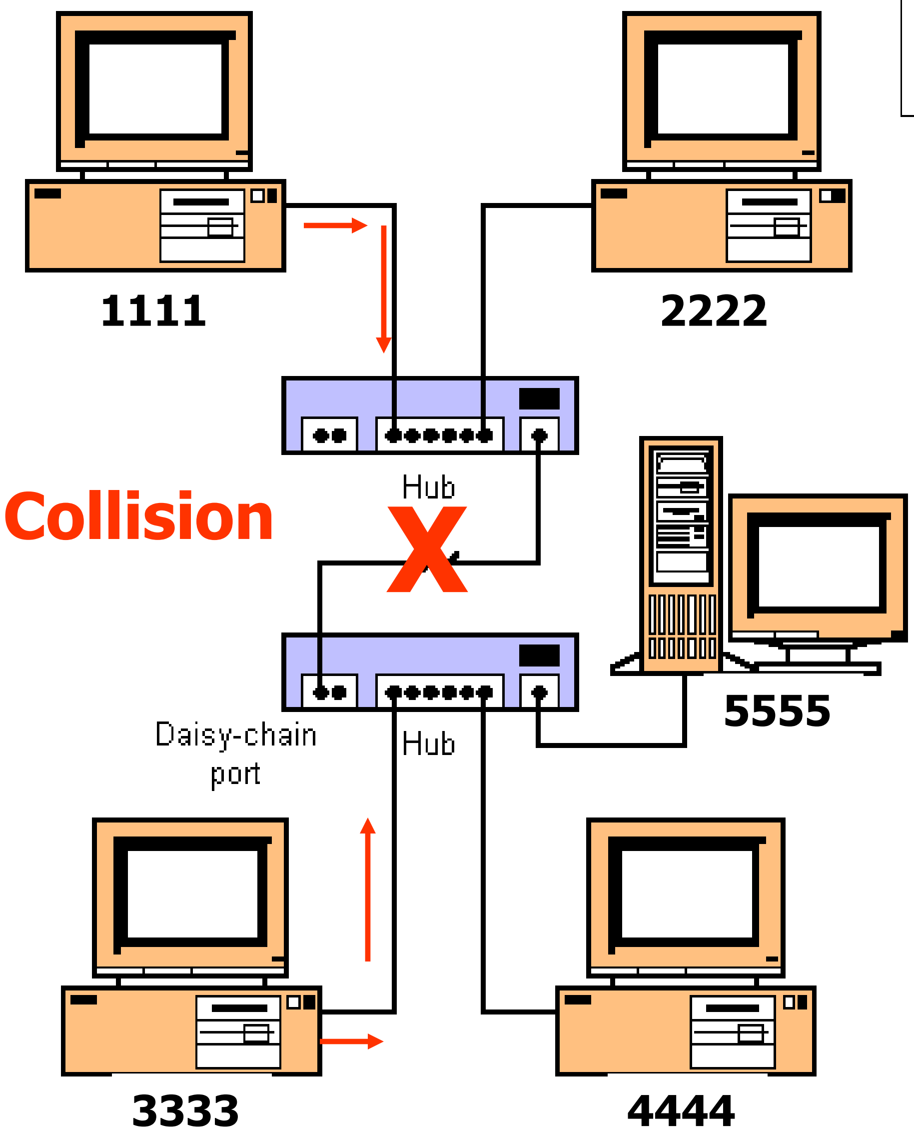


Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	2222	1111				

- What happens when two host on the same hub, or when multiple hubs are connected, transmit at the same time?

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	4444	3333				

Sending and receiving Ethernet frames via a hub

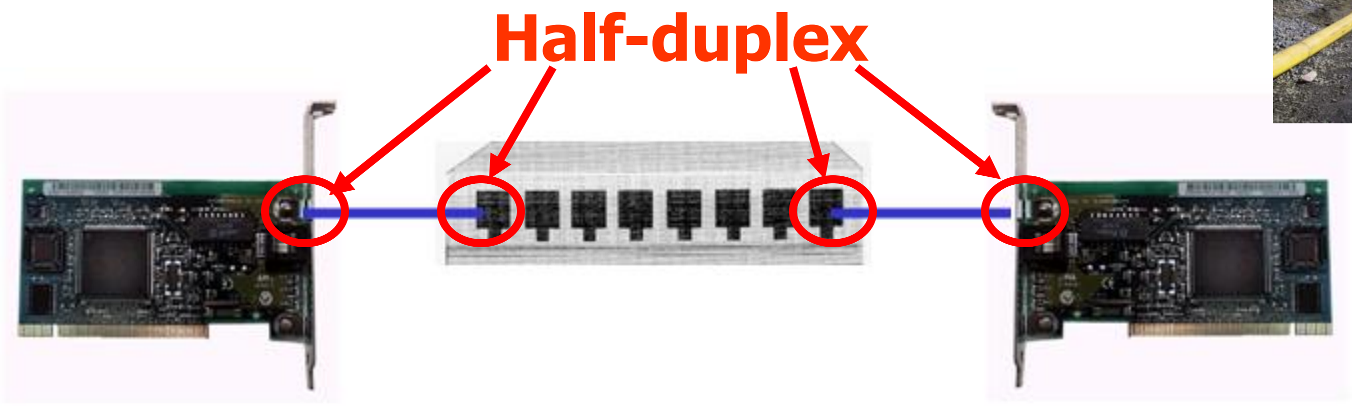


Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	2222	1111				

- Collision occurs.
- Although, hubs have little latency, CSMA/CD requires resending of frames and adds latency.

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	4444	3333				

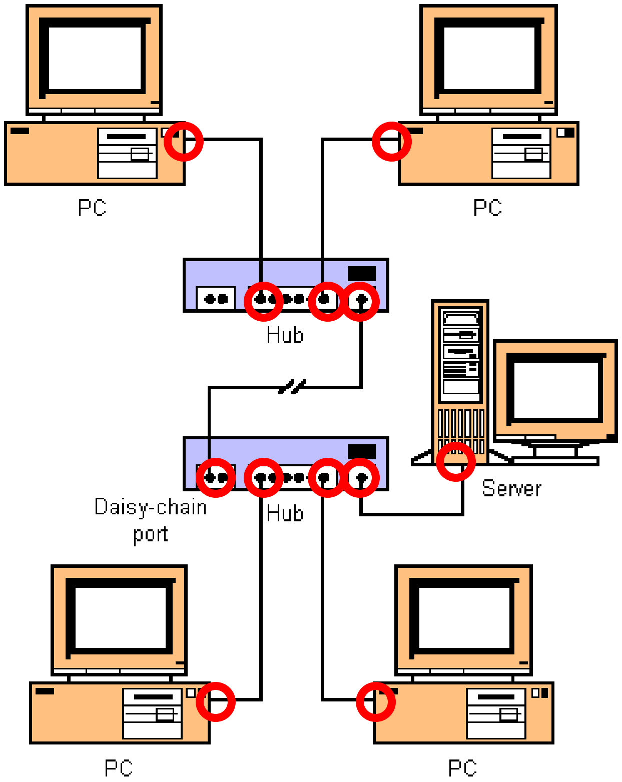
Half-duplex (Introduction)



- Hubs operate only in Half-duplex.
- **Half-duplex** means that only one end can send at a time.
- The other end of the link, Ethernet NIC or another Hub (or switch – later) must also be in Half-duplex mode
- With half-duplex NICs, a host can only transmit or receive, not both at the same time, or a collision will occur.
- When multiple devices are connected to a hub or series of hubs, only one device can transmit.
- Uses CSMA/CD.
- If the a carrier is detected, then the NIC will not transmit.
- Ethernet hubs and repeaters can only operate in half-duplex mode.

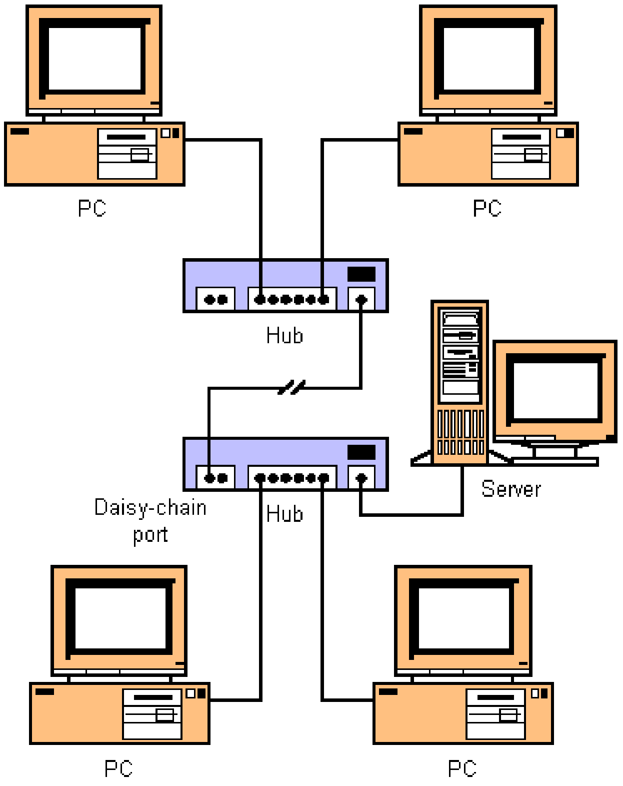
Half-Duplex mode

- All of these Ethernet NICs and ports on the hubs are operating in Half-Duplex mode.
- When multiple devices are connected to a hub or series of hubs, only one device can transmit.



Collision Domain: Shared Access

- **Collision domain (**Wikipedia)**:** A group of Ethernet or Fast Ethernet devices in a CSMA/CD LAN that are connected by repeaters/hubs and compete for access on the network.
  - Only one device in the collision domain may transmit at any one time, and the other devices in the domain listen to the network in order to avoid data collisions.
  - A collision domain is sometimes referred to as an Ethernet segment.
- If you connect several computers to a single medium that is only connected by ***repeaters and hubs (Layer 1 devices***), you have a shared-access situation, and you have a single **collision domain**.



Full-duplex (More in next section)

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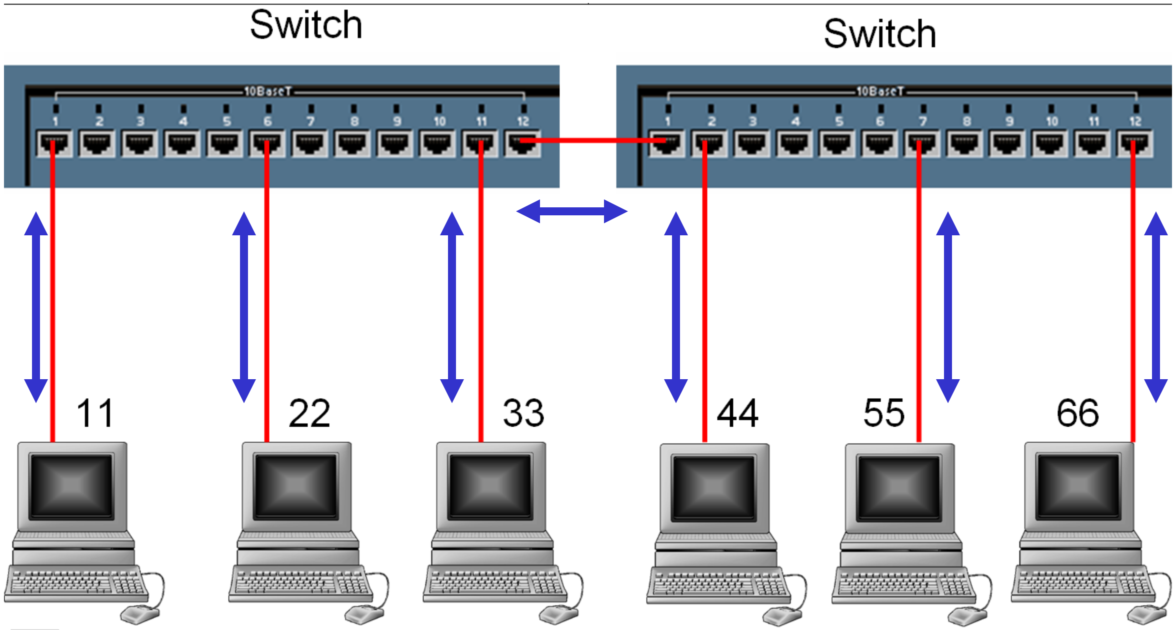

- **Full-duplex** is allows simultaneous communication between a pair of stations or devices.
- Full-duplex allows devices to <u>send and receive at the same time</u>.
- Both ends of the link must be in full-duplex mode.
- Most **<u>switches</u>** operate at either full-duplex but can operate in half-duplex.
- If a hub is connected to a switch, the switch port must be in half-duplex.
- The collision domain will end at the switch port.

Where are the collision domains?
What would be the duplex settings?

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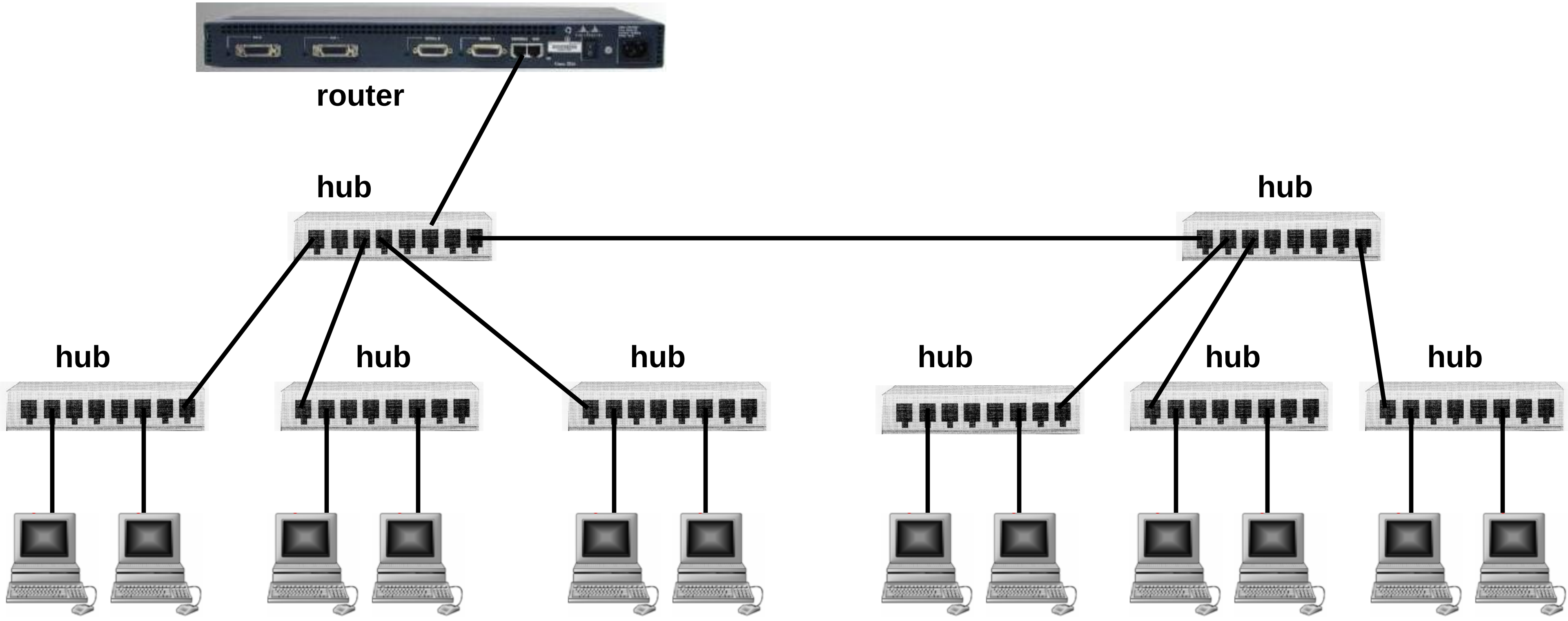

Where are the collision domains?

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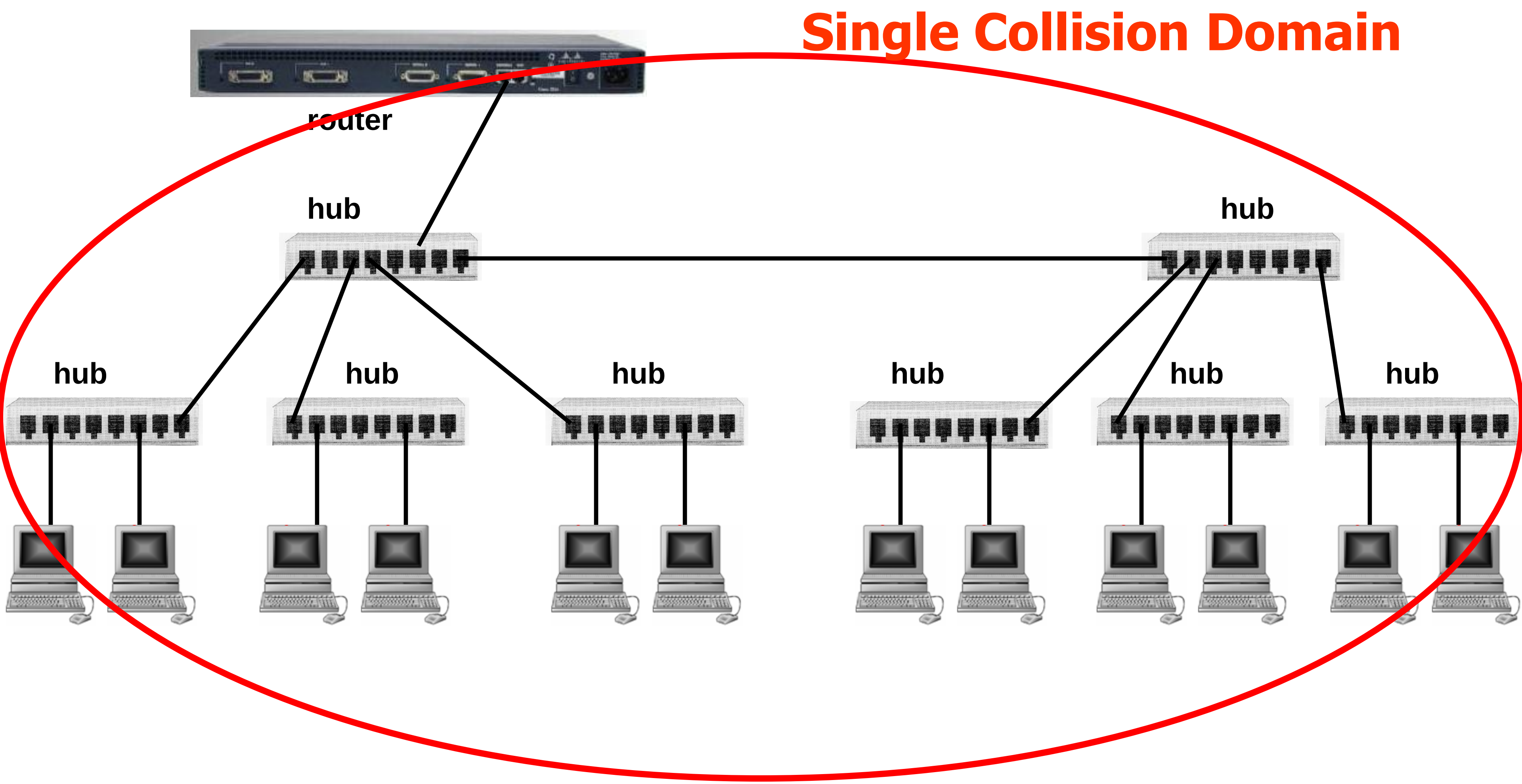
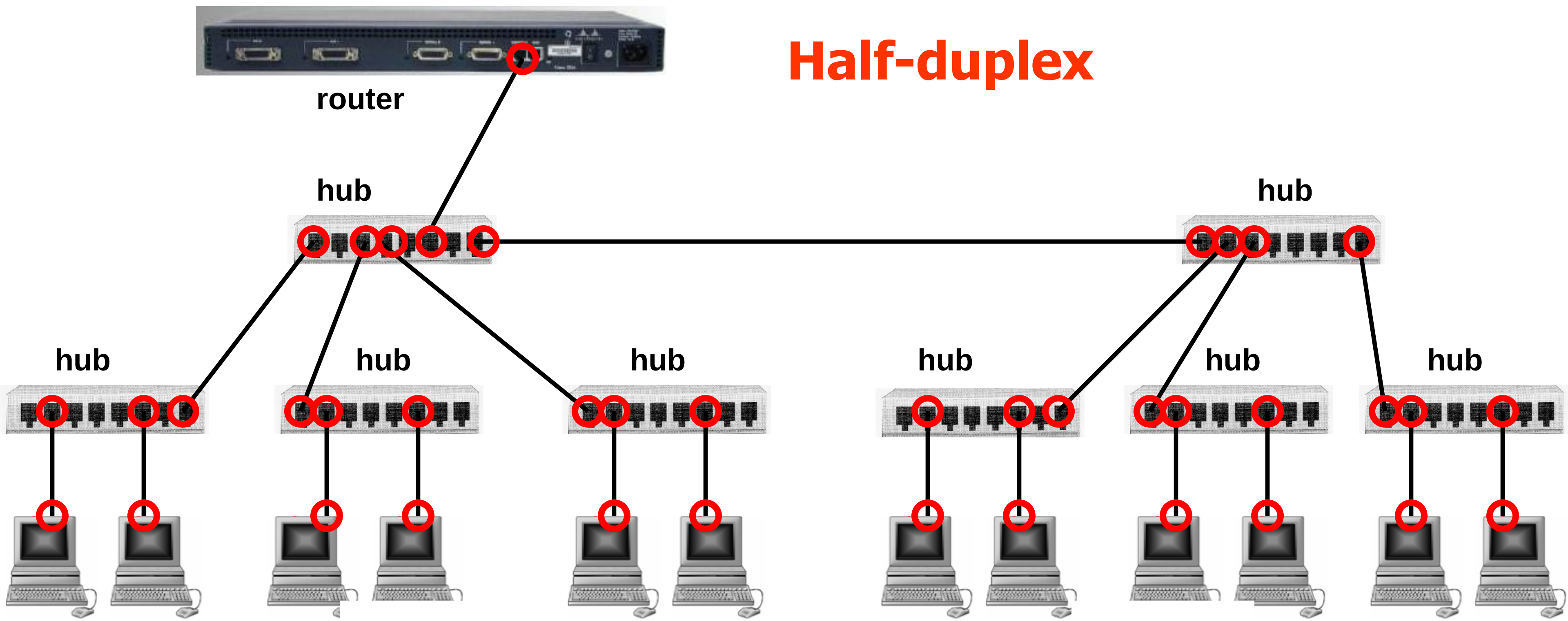
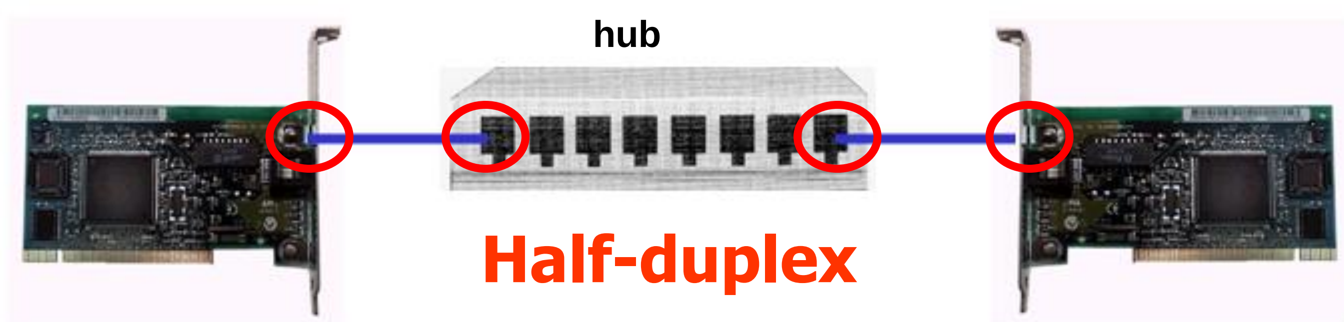


What would be the duplex settings?





Where are the collision domains?
What would be the duplex settings?

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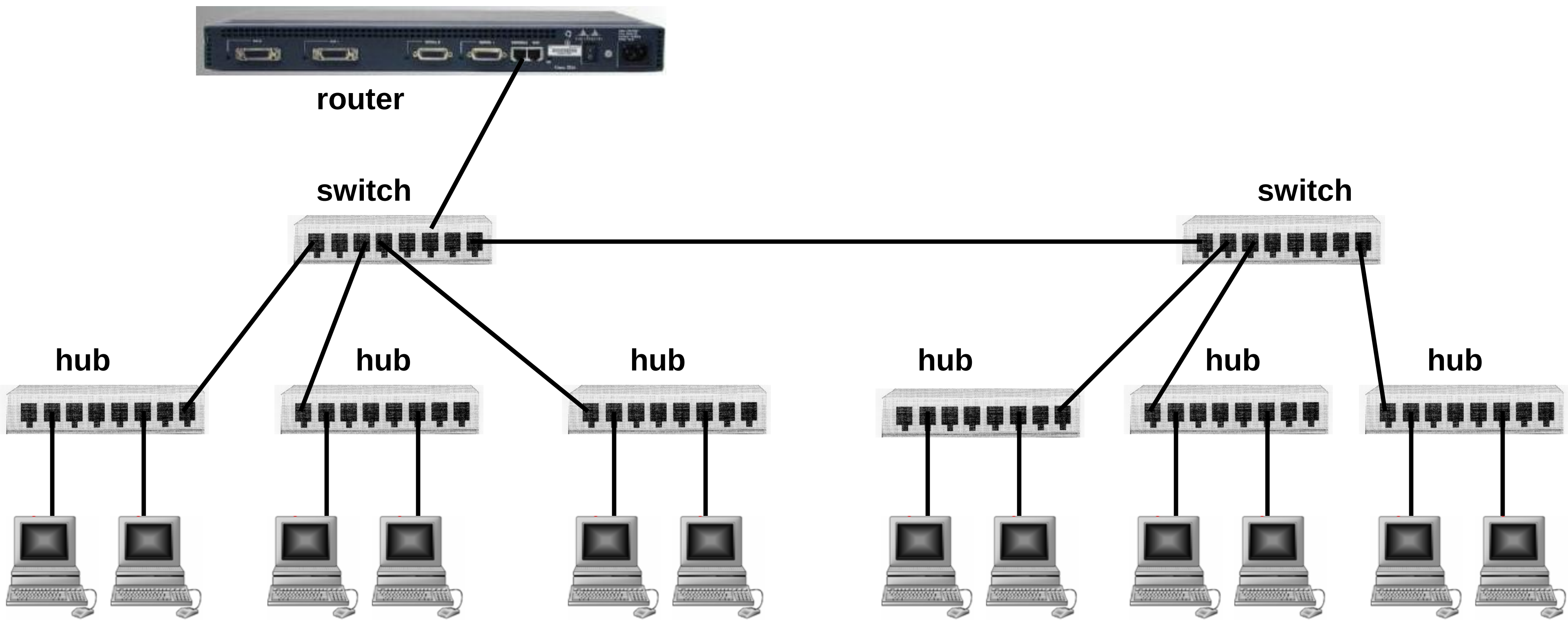
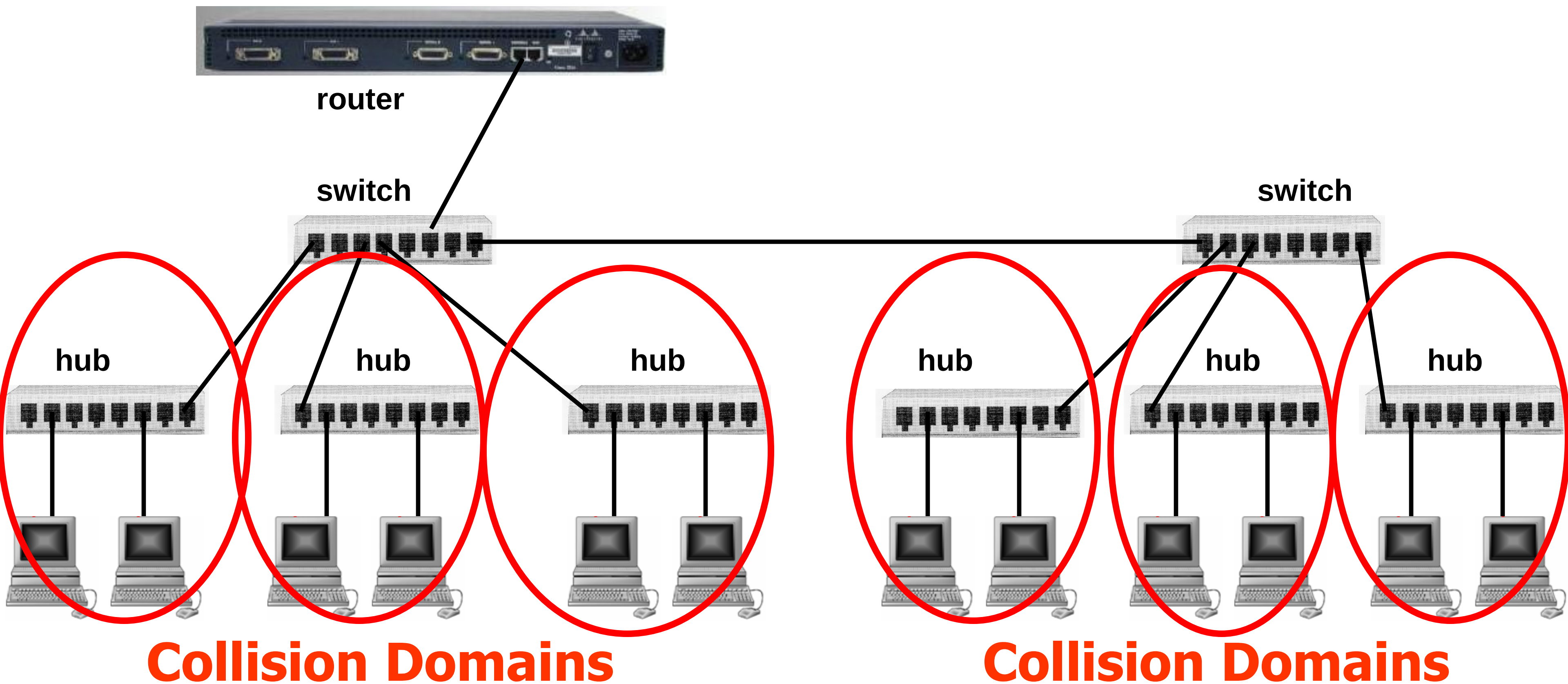


Where are the collision domains?
What would be the duplex settings?



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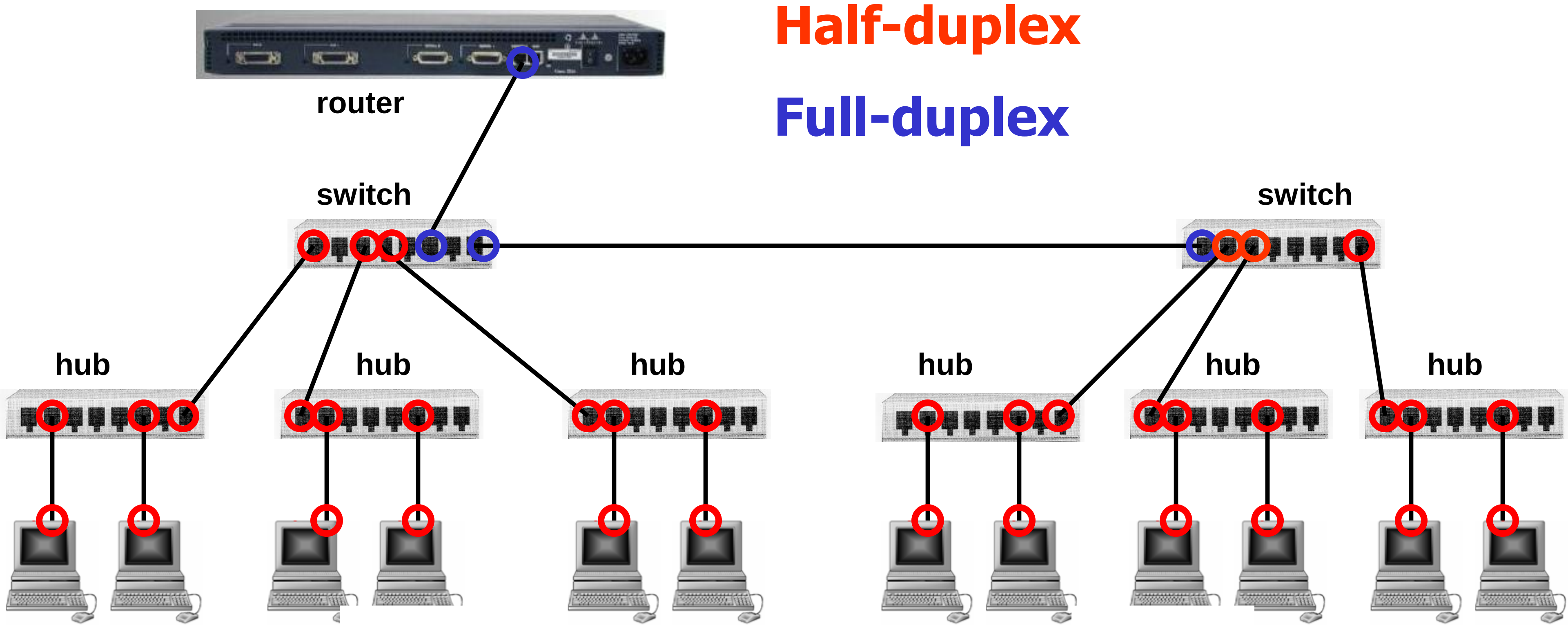
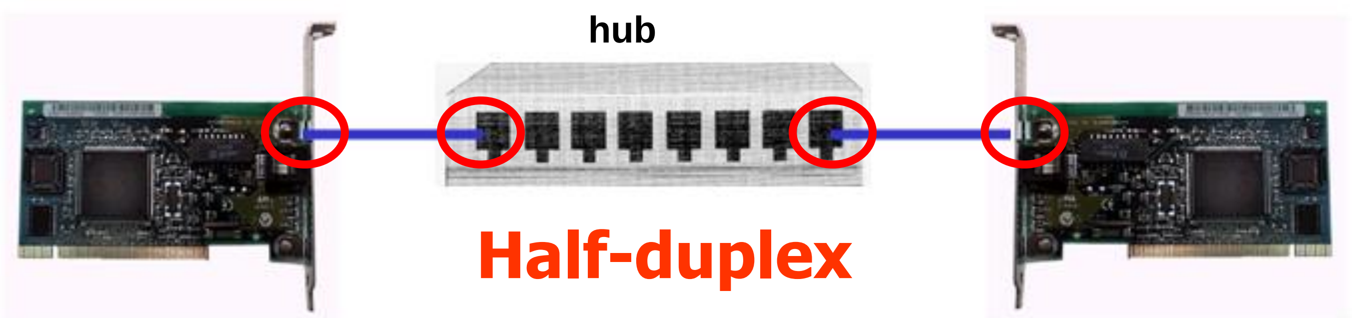
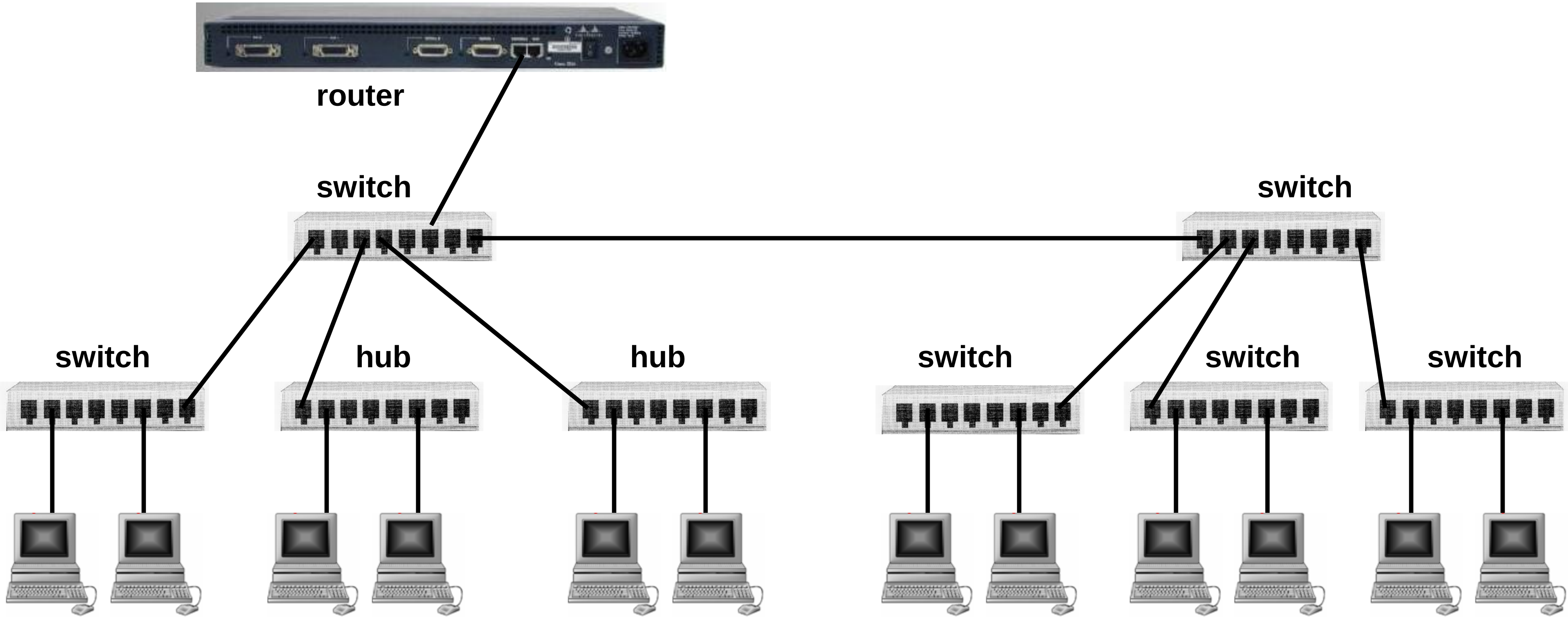




Where are the collision domains?
What would be the duplex settings?



Where are the collision domains?

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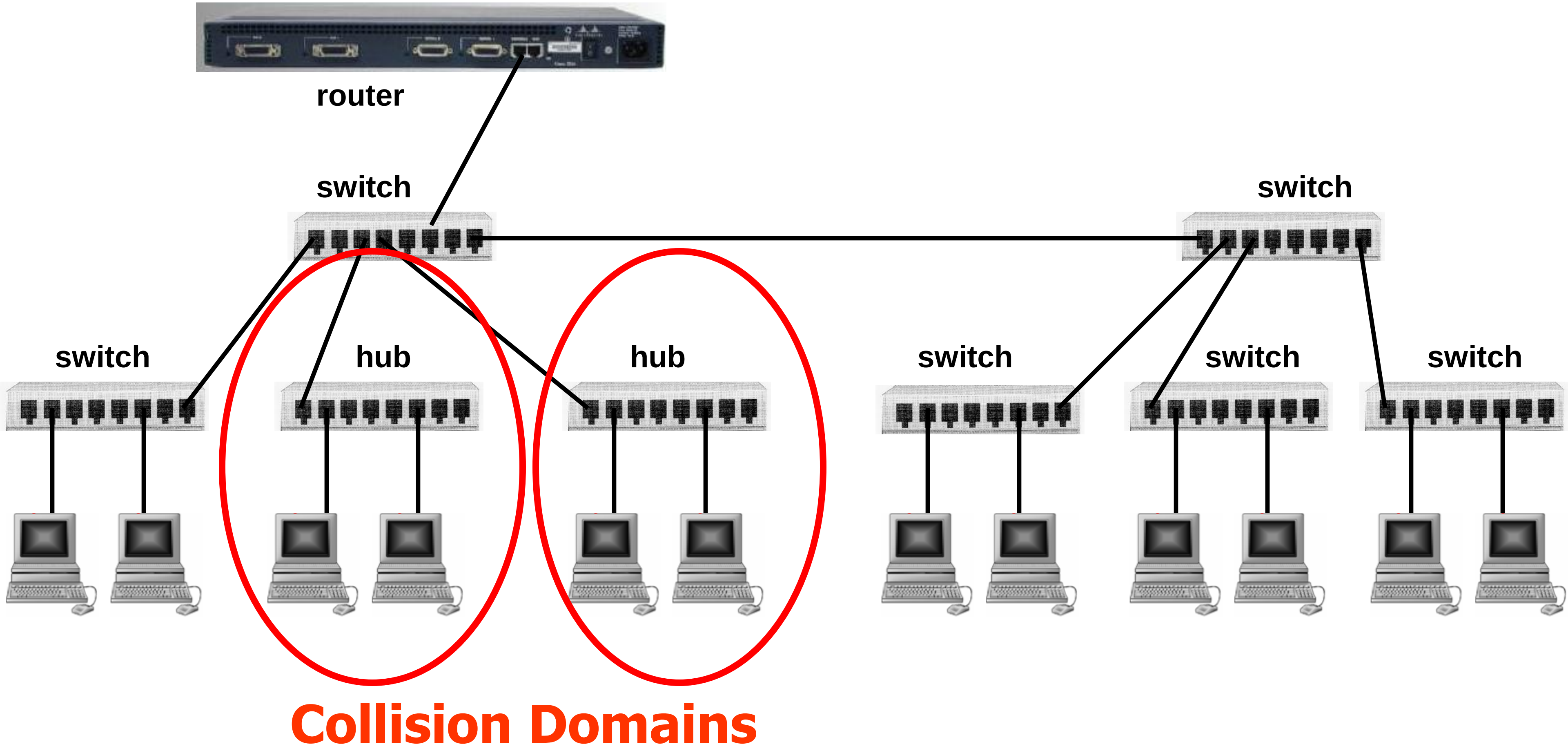
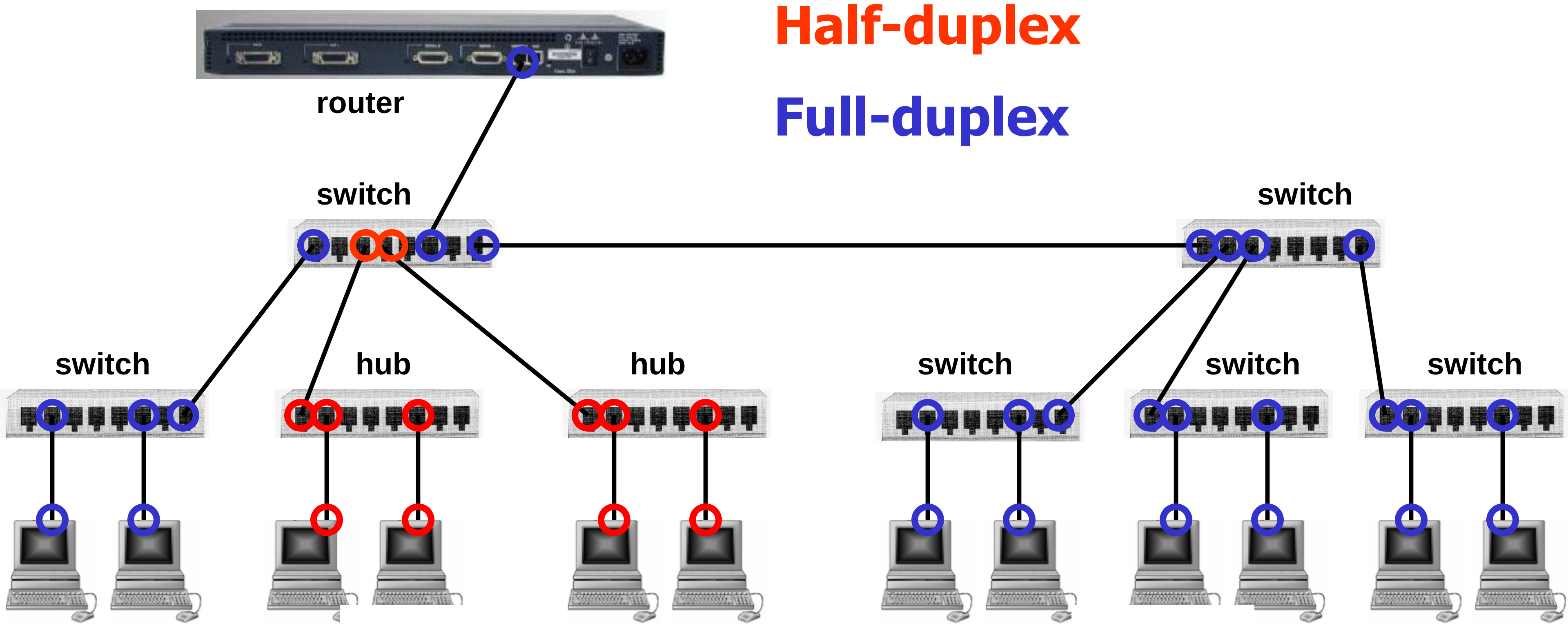
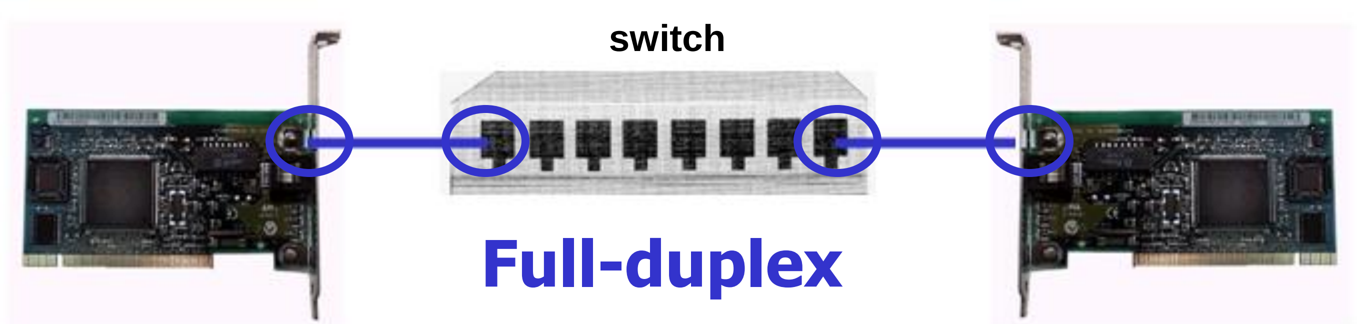
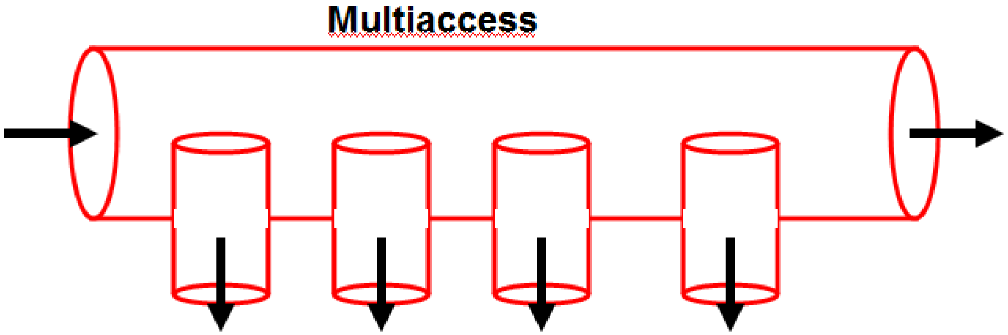


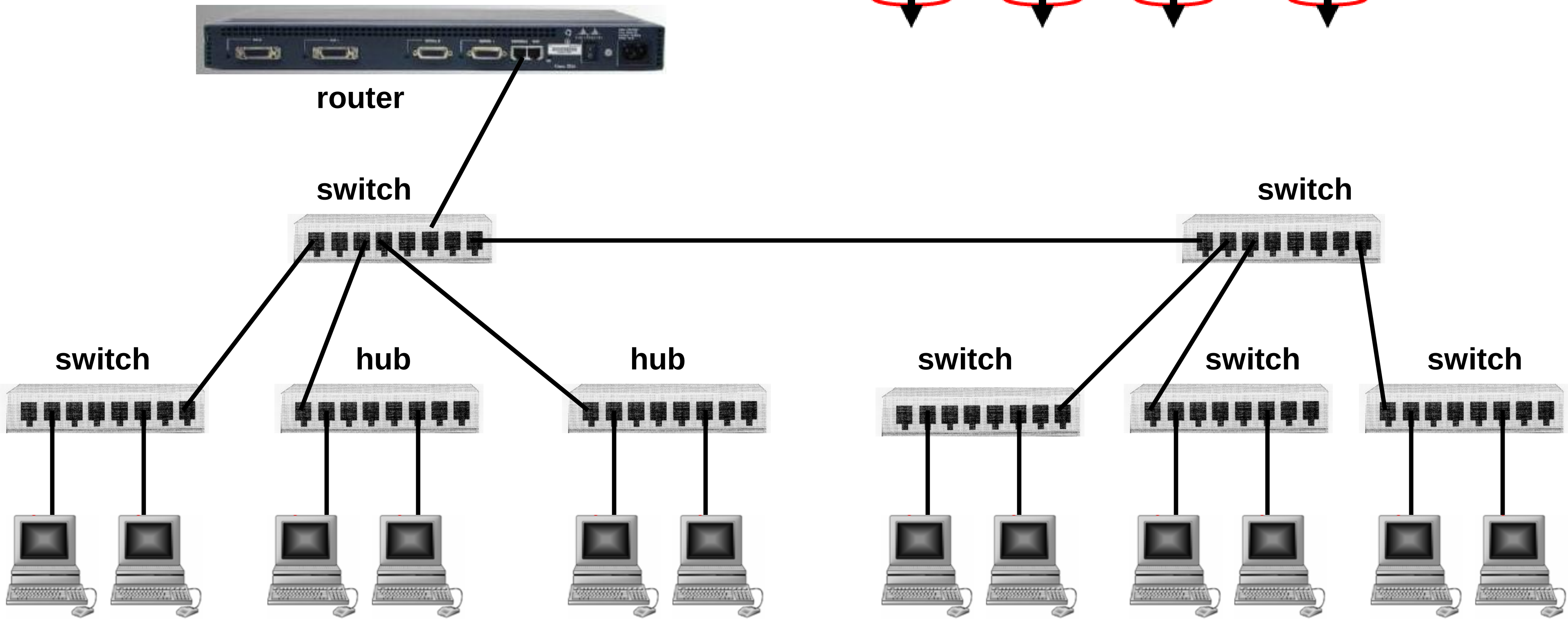
What would be the duplex settings?





All scenarios are multiaccess networks





Ethernet Fundamentals Overview: Part 1 (Mod 6)

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CIS 81 and CST 311

Rick Graziani

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Spring 2006